BLUE PRINT

CHAPTER	VSAQ (2M)	SAQ (4M)	LAQ (8M)	Total Marks
1. Physical World	1	–	–	2
2. Units & Measurements	1	–	–	2
3. Motion in A Straight Line	–	1	–	4
4. Motion in A Plane	1	1	–	6
5. Laws of Motion	1	1	–	6
6. Work, Energy & Power	–	–	1	8
7. System of Particles & Rotational Motion	2	1	–	8
8. Oscillations	–	–	1	8
9. Gravitation	–	1	–	4
10. Mechanical Properties of Solids	–	1	–	4
11. Mechanical Properties of Fluids	2	–	–	4
12. Thermal Properties of Matter	2	1	–	8
13. Thermodynamics	(1)	(1)	1	6 or 8
14. Kinetic Theory of Gases	(2)	1	–	4
Total Number of Questions	10	8	3	76

1. This Blue print is prepared according to the 'Model Question Paper' issued by B.I.E.

2. Please, note that, at times, the public question paper may get slight deviation from the above given Blue Print.

01 Physical World

LAQ (0) - 0 × 8 = 0M	
SAQ (0) - 0 × 4 = 0M	
VSAQ(1) - 1 × 2 = 2M	
Total Marks	= 2M

VERY SHORT ANSWER QUESTIONS (2 MARKS)

01. What is Physics ? TS Mar 16, May 22

Ans: Physics is the branch of science which deals with the physical properties of matter and their energies.

02. What are the fundamental forces in nature ? TS May 18

Ans: Gravitational force, Electromagnetic force, Strong nuclear force and weak nuclear force are the fundamental forces in nature.

03. What is the discovery of C.V. Raman ?

Mar 14; AP Mar 18, 20, May 16, 18; TS Mar 17, 18, 19, 20

Ans: The discovery of C.V. Raman is **Raman effect**, which deals with scattering of light by molecules of a medium when they are excited to vibrational energy levels.

04. What is the contribution of S. Chandra Sekhar to physics ?

AP Mar 15, 16, 17, June 15; TS Mar 15, 19, June 15

Ans: Chandra Sekhar limit, structure and evolution of stars.

THE END

02 Units And Measurements

LAQ (0)	- 0 × 8 = 0M
SAQ (0)	- 0 × 4 = 0M
VSAQ(1)	- 1 × 2 = 2M
Total Marks	= 2M

VERY SHORT ANSWER QUESTIONS (2 MARKS)

01. Distinguish between accuracy and precision.
AP Mar 15, 16, May 16, June 15; TS Mar 15, May 18

Ans: The accuracy of a measurement is a measure of how close the measured value is to the true value of the quantity.
Precision tells us to what resolution or limit the quantity is measured by an instrument.
Accuracy depends on errors and also on the precision of the measuring instrument.
Precision depends on the least count of the measuring instrument.

(or)

Accuracy	Precision
1) It is defined as the closeness of the measured value to the true value.	It is defined as to what resolution the quantity is measured.
2) It depends on the minimization of errors.	It depends on the least count of the measuring instrument.

02. Distinguish between fundamental units and derived units. AP May 14; TS Mar 16, 19; May 22

Ans: The units of fundamental physical quantities are called fundamental units.
Eg: Kg, m, sec, etc...
The units of derived physical quantities are called derived units.
Eg: ms^{-1}, J, ms^{-2} etc.

03. What is dimensional analysis ?

Ans: Representing the unit of derived quantity in terms of units of fundamental physical quantities by raising the powers of fundamental quantities is known as dimensional analysis. (or)
The dimensions of a physical quantity are the powers to which the units of base quantities are raised to represent a derived unit of that quantity.

Eg: Force $= [M^1L^1T^{-2}]$.

04. Express unified atomic mass unit in kg. TS Mar 18, May 22

Ans: Unified atomic mass unit (a.m.u)

$$\left(\frac{1}{12}\right)^{th} \text{ of mass of carbon atom } = \frac{1}{12}\times(C^{12}) = \frac{1}{12}\left[\frac{12\times10^{-3}}{6.02\times10^{23}}\right] = 1.66\times10^{-27}\text{ kg}.$$

05. How can systematic errors be minimised or eliminated ?
AP Mar 14 , 17, 18, May 22; TS Mar 17

Ans: Systematic errors can be minimised by improving experimental techniques, selecting better instruments and removing personal bias as far as possible.

06. The velocity of a body is given by $V = At^2 + Bt + C$. If V and t are expressed in S.I, what are the units of A, B and C ? AP May 07

Ans: The velocity of a body is given by $V = At^2 + Bt + C$ (in S.I).

Dimensional formula of V is $[LT^{-1}]$, dimensional formula of t is $[T]$.

Where S.I units of L is m and T is sec.

According to the principle of homogeneity,

Dimensional formula of V = Dimensional formula of $At^2 \Rightarrow LT^{-1} = AT^2 \Rightarrow A = [LT^{-3}]$.

Dimensional formula of V = Dimensional Formula of $Bt \Rightarrow LT^{-1} = BT \Rightarrow B = [LT^{-2}]$.

Dimensional formula of V = Dimensional Formula of $C \Rightarrow C = [LT^{-1}]$.

$\therefore$ Dimensional formula of the constants A, B and C are LT^{-3}, LT^{-2} and LT^{-1}.

$\therefore$ The S.I unit of A, B and C are ms^{-3}, ms^{-2} and ms^{-1}.

07. The error in measurement of radius of a sphere is 1%. What is the error in the measurement of volume ? **AP Mar 19**

Ans: We know, $V \propto r^3$.

$$\therefore \left(\frac{\Delta V}{V}\right) \times 100 = 3\left(\frac{\Delta r}{r}\right) \times 100.$$

But given, $\frac{\Delta r}{r} \times 100 = 1\%$.

Hence, $\frac{\Delta V}{V} \times 100 = 3(1\%) = 3\%$.

08. The percentage error in the mass and speed are 2% and 3% respectively. What is the maximum error in kinetic energy calculated using these quantities ?

AP May 18, Mar 20; TS Mar 20

Ans: $K = \frac{1}{2}mv^2 \Rightarrow K \propto mv^2$

$\frac{\Delta K}{K} \times 100 = \left(\frac{\Delta m}{m} \times 100\right) + 2\left(\frac{\Delta v}{v} \times 100\right)$. Given, $\frac{\Delta m}{m} \times 100 = 2\%$ and $\frac{\Delta v}{v} \times 100 = 3\%$.

$$\therefore \frac{\Delta K}{K} \times 100 = 2\% + 2(3\%) = 8\%.$$

09. What are significant figures and what do they represent when reporting the result of a measurement ? **TS Mar 18**

Ans: In a measurement, the reliable digits plus the first uncertain digits are known as significant figures. They represent precision of measurement when reporting result. (or)

The number of reliable digits in a number with first uncertain digit are called significant figures.

10. Why do we have different units for the same physical quantity ? **TS June 15, May 16, 22**

Ans: We have different system of measurements like C.G.S and M.K.S systems, we have different units for the same physical quantity.

Eg: 1) Energy - Joule in SI system and erg in C.G.S system.

2) Force - Newton in SI system and dyne in C.G.S system.

******THE END******

03 Motion in A Straight Line

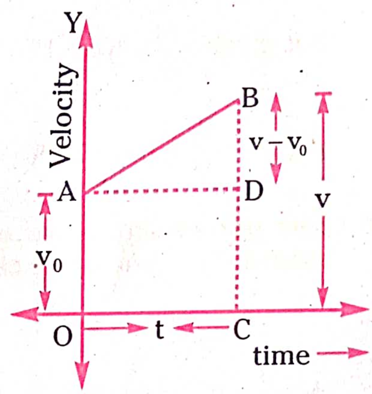
LAQ (0)	- 0 × 8 = 0M
SAQ (1)	- 1 × 4 = 4M
VSAQ(0)	- 0 × 2 = 0M
Total Marks	= 4M

SHORT ANSWER QUESTIONS (4 MARKS)

01. Derive the equation $x = v_0 t + \frac{1}{2}at^2$ using graphical method where the terms have usual meaning. **TS May 11, 16; Mar 19**

Ans: Consider a body moving with uniform acceleration 'a'. Let initial velocity of the body is 'v_0' and it gains a velocity 'v' after 't' seconds. The graph plotted between velocity and time is a straight line as shown in the figure. The area under v-t graph gives the displacement of the body.

From the diagram, $OC = AD = t$, $OA = CD = v_0$,



$BC = BD + CD \Rightarrow BD = BC - CD \Rightarrow BD = v - v_0$ —— (1)

So, displacement is area of OABC

x = Area of rectangle ADCO + area of triangle ABD

$\Rightarrow x = (OC)(OA) + \frac{1}{2}(AD)(BD) \Rightarrow x = (t)(v_0) + \frac{1}{2}(t)(v - v_0)$

(from (1)) —— (2)

But, $a = \frac{v - v_0}{t} \Rightarrow v - v_0 = at$.

Substituting, this value in equation (2), $x = v_0 t + \frac{1}{2}(t)(at) \Rightarrow x = v_0 t + \frac{1}{2}at^2$.

02. Explain the terms 'average velocity' and 'instantaneous velocity'. When are they equal ? **Mar 19**

Ans: **Average velocity:** Average velocity is the ratio of the total displacement to the total time interval in which the displacement occurs. $\vec{v}_{avg} = \frac{\Delta\vec{x}}{\Delta t} = \frac{\vec{x}_2 - \vec{x}_1}{t_2 - t_1}$.

It is independent of path followed by the particle between initial and final positions.

Instantaneous velocity: The velocity of the particle at any instant of time is called instantaneous velocity.

Instantaneous velocity, $\vec{v} = \underset{\Delta t \to 0}{\mathrm{Lt}} \frac{\Delta\vec{x}}{\Delta t} = \frac{d\vec{x}}{dt}$.

In uniform motion, the instantaneous velocity of a body is equal to the average velocity.

Average velocity belongs to entire motion of the body.

Instantaneous velocity belongs to particular instant of time.

03. **A ball is thrown vertically upwards with a velocity of $20\ ms^{-1}$ from the top of a multistorey building. The height of the point from where the ball is thrown is $25.0\ m$ from the ground.**
a) How high will the ball rise ? and
b) How long will it be before the ball hits the ground ? Take $g = 10\ ms^{-2}$ (actual value is $9.8\ ms^{-2}$).
TS Mar 15, May 17; AP Mar 15; SOLVED PROBLEM

Ans: **a)** Let us take the y-axis in the vertically upward direction with zero at the ground.
Now, $v_0 = +20\ ms^{-1}$, $a = -g = -10\ ms^{-2}$, $v = 0\ ms^{-1}$.
If the ball rises to height 'y' from the point of launch, then using the equation
$v^2 = v_0^2 + 2a(y - y_0)$, we get $0 = (20)^2 + 2(-10)(y - y_0)$

Solving, we get $(y - y_0) = 20\ m$ or $h = \frac{v_0^2}{2g} = \frac{20 \times 20}{2 \times 10} = 20\ m$.

b) We can solve this part of the problem as follows:

The total time taken can be calculated by using the equation, $h = -v_0 t + \frac{1}{2} g t^2$.

Put $h = 25\ m$, $v_0 = 20\ ms^{-1}$, $g = 10\ ms^{-2}$

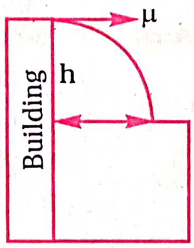
$25 = -20t + \frac{1}{2} 10t^2$ (or) $5t^2 - 20t - 25 = 0$.

Solving this quadratic equation for 't', $\left[\begin{array}{l} ax^2 + bx + c = 0 \\ x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \end{array}\right]$ $\therefore t = \frac{20 \pm \sqrt{900}}{10} = 5\ sec$.

04. **A man runs across the roof of a tall building and jumps horizontally on to the (locus) roof of an adjacent building. If his speed is 9 mts and the horizontal distance between the building is 10 mts and the height difference between the roofs in 9 mts. Will he be able to land on the next building ? [Take $g = 10\ ms^{-2}$]**
TS Mar 18

Ans: Height velocity $= 9\ ms^{-1}$, Height difference $h = 9\ m$, Acceleration due to gravity $(g) = 10\ ms^{-2}$,

Distance between the buildings $d = 10\ m$.



Horizontal range (R) $= u\sqrt{\frac{2h}{g}} \Rightarrow R = 9\sqrt{\frac{2 \times 9}{10}} = 9\sqrt{1.8} = 12.074\ m$.

Horizontal range is greater than distance between the two buildings.

Hence, the man is able to land on the next building safely.

05. **A car travels the first third of a distance with a speed of 10 kmph, the second third at 20 kmph and the last third at 60 kmph. What is its mean speed over the entire distance ?**
May 14, 22; AP Mar 18; TS Mar 16; PROBLEM

Ans: Given, $v_1 = 10$ kmph, $v_2 = 20$ kmph and $v_3 = 60$ kmph

$$v_{avg} = \frac{3v_1v_2v_3}{v_1v_2 + v_2v_3 + v_3v_1} = \frac{3(10)(20)(60)}{(10 \times 20) + (20 \times 60) + (60 \times 10)} = \frac{3600}{2000} = 18\ \text{kmph}.$$

06. **A bullet moving with a speed of $150\ ms^{-1}$ strikes a tree and penetrates 3.5 cm before stopping. What is the magnitude of its retardation in the tree and the time taken for it to stop after striking the tree ?**
TS May 18; PROBLEM

Ans: Initial speed, $u = 150\ ms^{-1}$, Final speed, $v = 0$, Distance travelled, $s = 3.5 \times 10^{-2}\ m$.

Let magnitude of retardation is 'a', then acceleration $=-a$.

Use $v^2-u^2=2(-a)s \Rightarrow 0^2-(150)^2=2\times(-a)\times 3.5\times 10^{-2}$

$$\Rightarrow a=\frac{150\times 150}{2\times 3.5\times 10^{-2}}=3214.28\times 10^2=3.214\times 10^5\ ms^{-2}.$$

Let, the time taken for it to stop is 't'.

From $v=u+(-a)t \Rightarrow 0=150-3.214\times 10^5 t \Rightarrow 3.214\times 10^5 t=150 \Rightarrow t=\frac{150}{3.214\times 10^5}=4.667\times 10^{-4}\ s$.

07. A particle moves in a straight line with uniform acceleration. Its velocity at time $t=0$ is v_1 and at time $t=t$ is v_2. The average velocity of the particle in this time interval is $(v_1+v_2)/2$. Is this correct ? Substantiate your answer ?

Ans: Yes, it is correct.

Consider, a particle moving with uniform acceleration 'a' along a straight line (say x-axis). Its velocity is 'v_1' at time $t=0$ at origin and it reaches a position 'x' in a time 't' and its velocity became 'v_2'. Then, average velocity over time interval 't' is

$$v_{avg}=\frac{\Delta x}{\Delta t}=\frac{x-0}{t-0}=\frac{x}{t} \text{ ——— (1)}$$

The displacement of the particle in this time interval 't' is

$$x=v_1 t+\frac{1}{2}at^2 \Rightarrow \frac{x}{t}=v_1+\frac{1}{2}at \text{ but, } a=\frac{v_2-v_1}{t}$$

$$\therefore \frac{x}{t}=v_1+\frac{1}{2}\left(\frac{v_2-v_1}{t}\right)t \Rightarrow \frac{x}{t}=v_1+\frac{1}{2}(v_2-v_1)=v_1+\frac{v_2-v_1}{2}=\frac{2v_1+v_2-v_1}{2} \Rightarrow \frac{x}{t}=\frac{(v_1+v_2)}{2} \text{ ——— (2)}$$

From equation (1) and (2), average velocity of the particle is equal to $\frac{(v_1+v_2)}{2}$.

08. A parachutist flying in an aeroplane jumps when it is at a height of 3 km above the ground. He opens his parachute when he is at about 1 km above the ground. Describe his motion.

TS Mar 17

Ans: **Motion before opening the parachute:** A parachutist has jumped from an aeroplane flying horizontally at a height of 3 km above the ground. Now, he has two dimensional motion.

1) He has horizontal motion, $x=vt$ due to inertia of motion of the aeroplane. Here, 'v' is velocity of aeroplane.

2) He has vertical motion downwards due to gravitational force of attraction $y=0+(1/2)gt^2$.

So, he follows a parabolic path till he opens the parachute at a height 1 km above the ground.

Motion after opening the parachute: After parachute is opened, air resistance and air buoyancy acts on the system in upward direction along with gravitational force in downward direction. Due to these forces, the net acceleration will become zero after falling through certain height. Thereafter, the system attains a constant velocity called terminal velocity. Further he falls along a straight line downwards with the same terminal velocity till he reaches the ground.

09. A ball is dropped from the roof of a tall building and simultaneously another ball is thrown horizontally with some velocity from the same roof. Which ball lands first ? Explain your answer.

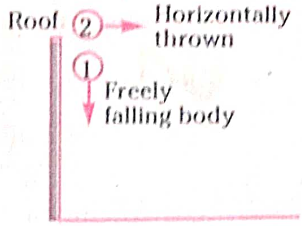
TS June 15

Ans: Both the balls reach the ground simultaneously.

1) Consider, a ball dropped from the roof of height 'h', the time taken by the ball to reach the ground is 't_1', then

Initial velocity $v_0=0$, acceleration $a=+g$,

Distance travelled $x = h$ and time $t = t_1$.



From $x = v_0 t + \frac{1}{2}at^2$, $h = (0)t_1 + \frac{1}{2}gt_1^2$

$\Rightarrow h = \frac{1}{2}gt_1^2 \Rightarrow t_1 = \sqrt{\frac{2h}{g}}$ —— (1)

2) Consider, a ball thrown horizontally with velocity 'u' from the same roof, the time taken by the ball to reach the ground is 't_2'. Here, initial vertical velocity, $v_0 = u\cos 90^\circ = 0$.

Acceleration $a = +g$, distance travelled in vertical direction $y = h$ and time $t = t_2$.

From $y = v_0 t + \frac{1}{2}at^2 \Rightarrow h = (0)t_2 + \frac{1}{2}gt_2^2 = \frac{1}{2}gt_2^2$. $\therefore t_2 = \sqrt{\frac{2h}{g}}$ —— (2)

From (1), (2), it is proved that $t_1 = t_2$.

Hence, both reach the ground at the same instant of time.

10. A man walks on a straight road from his home to a market 2.5 km away with a speed of 5 kmh^{-1}. Finding the market closed, he instantly turns and walks back home with a speed of 7.5 kmh^{-1}. What is the a) magnitude of average velocity and b) average speed of the man over the time interval 0 to 50 min? **May 18, Mar 19; TS Mar 18, 20; PROBLEM**

Ans: Time taken to go from home to market is $t_1 = \frac{s}{v_1} = \frac{2.5}{5} \Rightarrow t_1 = \frac{1}{2}hr = 30\ min$.

Time taken by him to get back from market to home is $t_2 = \frac{s}{v_2} = \frac{2.5}{7.5} = \frac{1}{3}hr = 20\ min$.

We have to find average velocity and average speed over time interval 50 min which is equal to to and fro time of journey.

a) Magnitude of average velocity $= \frac{\text{total displacement}}{\text{total time}} = \frac{0}{50} = 0$.

b) Average speed $= \frac{\text{total distance}}{\text{total time}} = \frac{2.5+2.5}{(1/2)+(1/3)} = 6\ kmph$.

11. A car moving along a straight highway with a speed of 126 kmph is brought to a stop within a distance of 200 m. What is the retardation of the car (assumed uniform), and how long does it take for the car to stop? **AP Mar 20; ADD. PROBLEM**

Ans: Initial velocity of the car, $u = 126\ kmph = 35\ ms^{-1}$, Final velocity of the car, $v = 0$.

Distance covered by the car before coming to rest, $s = 200\ m$.

Retardation produced in the car $= a$.

From third equation of motion, 'a' can be calculated using the formula, $v^2 - u^2 = 2as$

$\Rightarrow (0)^2 - (35)^2 = 2 \times a \times 200 \Rightarrow a = \frac{35 \times 35}{2 \times 200} = -3.06\ ms^{-2}$.

From first equation of motion, time (t) taken by the car to stop can be obtained using the formula, $v = u + at \Rightarrow t = \frac{v-u}{a} = \frac{-35}{-3.06} = 11.44\ s$.

THE END

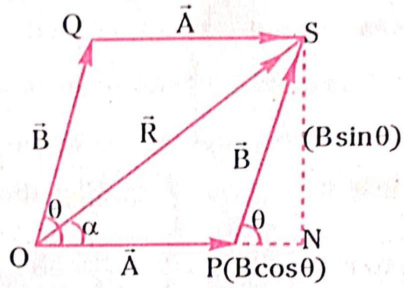
04 Motion in A Plane

LAQ (0) - 0 × 8 = 0M
SAQ (1) - 1 × 4 = 4M
VSAQ(1) - 1 × 2 = 2M
Total Marks = 6M

SHORT ANSWER QUESTIONS (4 MARKS)

01. State parallelogram law of vectors. Derive an expression for the magnitude and direction of the resultant vector. Mar 14; AP Mar 20; TS Mar 16, 17, 20, May 17, 22

Ans: Statement: If two vectors are represented in magnitude and direction by the two adjacent sides of a parallelogram drawn from a point, then their resultant is represented in magnitude and direction by the diagonal passing through the same point.



Explanation:

Let $\vec{A}$ and $\vec{B}$ are two vectors represented by the two sides OP and OQ of a parallelogram OPSQ. The diagonal OS represents the resultant $\vec{R}$.

i.e., $\vec{R} = (\vec{A}+\vec{B})$ in magnitude and direction.

Expression for magnitude of the resultant (R):

Let us extend the line OP upto point N and draw a perpendicular from S to N. From the parallelogram OPSQ,

$\angle QOP = \angle SPN = \theta$;

$OP = QS = A$ (the magnitude of $\vec{A}$) —— (1), $OQ = PS = B$ (the magnitude of $\vec{B}$) —— (2)

and $OS = R$ (the magnitude of resultant $\vec{R}$) —— (3).

From right angled triangle PNS:

$\cos\theta = \dfrac{PN}{PS} \Rightarrow PN = PS\cos\theta \Rightarrow PN = B\cos\theta$ —— (4)

$\sin\theta = \dfrac{NS}{PS} \Rightarrow NS = PS\sin\theta \Rightarrow NS = B\sin\theta$ —— (5)

From the right angled triangle ONS:

$(OS)^2 = (ON)^2 + (NS)^2 \Rightarrow R^2 = (OP+PN)^2 + (NS)^2$ $(\because ON = OP+PN)$

$\Rightarrow R^2 = (OP)^2 + (PN)^2 + 2(OP)(PN) + (NS)^2$

$\Rightarrow R^2 = A^2 + B^2\cos^2\theta + 2AB\cos\theta + B^2\sin^2\theta$ [$\because$ From (1), (4), (5)]

$\Rightarrow R^2 = A^2 + B^2(\sin^2\theta + \cos^2\theta) + 2AB\cos\theta \Rightarrow R^2 = A^2 + B^2 + 2AB\cos\theta$ $(\because \sin^2\theta + \cos^2\theta = 1)$

$\therefore R = \sqrt{A^2 + B^2 + 2AB\cos\theta}$.

Direction of the resultant:

If the line of action of the vector $\vec{A}$ is taken as reference line, the resultant $\vec{R}$ makes an angle α with it. This angle indicates the direction of $\vec{R}$.

In the right angled triangle ONS,

$$\tan\theta = \frac{NS}{ON} = \frac{NS}{OP+PN} \quad (\because ON = OP + PN)$$

From equations (1), (4) and (5), $\tan\alpha = \dfrac{B\sin\theta}{A+B\cos\theta}$.

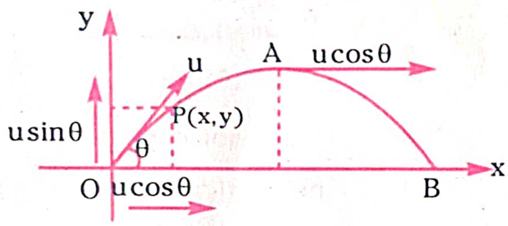
The direction of the resultant vector $\vec{R}$ is given by $\alpha = \tan^{-1}\left(\dfrac{B\sin\theta}{A+B\cos\theta}\right)$.

02. **Show that the trajectory of an object thrown at certain angle with the horizontal is a parabola.**

AP Mar 15, 16, 17, 18, 22; May 17, 18, June 15; TS Mar 15, 18, May 16, 22; June 15

Ans: **Projectile:** If a body is projected into air by a person at an angle other than $90°$ with the horizontal, then the body is called a Projectile.

Expression for the trajectory of an object: Consider a body projected from the point 'O' into air with an initial velocity 'u'. It is making an angle 'θ' with the horizontal as shown in the figure.



The path OAB is called the trajectory of the projectile as shown in the figure.

To consider the two dimensional motion of the body, we resolve the initial velocity 'u' into two rectangular components:

1) Horizontal component $u_x = u\cos\theta$,

2) Vertical component $u_y = u\sin\theta$.

Suppose the projectile is crossing the point 'P' after time 't'.

i) Its horizontal displacement 'x' is given by

$$x = u_x t + \frac{1}{2}a_x t^2 = (u\cos\theta)t + \frac{1}{2}(0)t^2 = (u\cos\theta)t \text{ —— (1)} \quad (\because a_x = 0)$$

ii) The vertical displacement 'y' is given by

$$y = u_y t + \frac{1}{2}a_y t^2 = (u\sin\theta)t + \frac{1}{2}(-g)t^2 \quad (\because a_y = -g)$$

$$\therefore\ y = (u\sin\theta)t - \frac{1}{2}gt^2 \text{ —— (2)}$$

From equation (1), $x = u\cos\theta t \Rightarrow t = \dfrac{x}{u\cos\theta}$ —— (3)

Using equation (3) in equation (2), we get, $y = u\sin\theta\left(\dfrac{x}{u\cos\theta}\right) - \dfrac{1}{2}g\left(\dfrac{x}{u\cos\theta}\right)^2$

The displacement in two dimensional motion is given by $y = (\tan\theta)x - \left(\frac{g}{2u^2\cos^2\theta}\right)x^2$

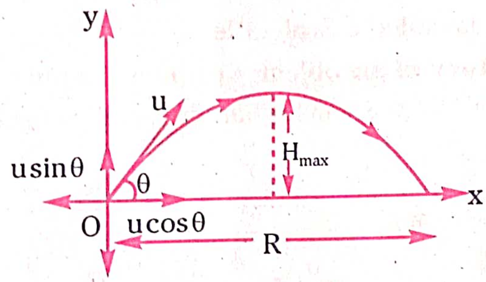
(Let $\tan\theta = A$ and $\frac{g}{2u^2\cos^2\theta} = B$). Then, $y = Ax - Bx^2$.

Result: This equation represents the equation of a parabola.

Hence, the trajectory of a projectile is a parabola.

03. Show that the maximum height and range of a projectile are $\frac{u^2\sin^2\theta}{2g}$ and $\frac{u^2\sin 2\theta}{g}$ respectively. Where the terms have their regular meanings. **AP Mar 12**

Ans: **Maximum height (H):** The greatest vertical displacement of a projectile during its journey is called maximum height (or) It is the height above the plane of projection at which the vertical component of velocity becomes zero.



For maximum height, we consider vertical displacement upto maximum height.

Initial vertical velocity $(u_y) = u\sin\theta$, Final vertical velocity $(v_y) = 0$.

Vertical acceleration $(a_y) = -g$, Vertical displacement $(s) = H_{max}$.

From equation of motion $v_y^2 - u_y^2 = 2a_y s \Rightarrow 0^2 - (u\sin\theta)^2 = 2(-g)H_{max} \Rightarrow u^2\sin^2\theta = 2gH_{max}$

$\therefore\ H_{max} = \frac{u^2\sin^2\theta}{2g}$.

Horizontal Range (R): The maximum horizontal displacement of a projectile when it reaches the horizontal plane of projection is called range (R). For range, we consider horizontal displacement during time of flight.

Initial horizontal velocity $(u_x) = u\cos\theta$, Horizontal acceleration $(a_x) = 0$,

Time of flight $(T) = \frac{2u\sin\theta}{g}$, Horizontal displacement $= R$.

Substituting in $s = ut + \frac{1}{2}at^2$

$R = (u\cos\theta)T = \frac{(u\cos\theta)(2u\sin\theta)}{g} = u^2\frac{(2\sin\theta\cdot\cos\theta)}{g} \Rightarrow R = \frac{u^2\sin 2\theta}{g}$. $[\because \sin 2\theta = 2\sin\theta\cos\theta]$

Maximum horizontal range: When a projectile is thrown at an angle $45°$ with the horizontal, the range becomes maximum.

$R_{max} = \frac{u^2\sin 2\theta}{g} = \frac{u^2\sin(2\times 45°)}{g} = \frac{u^2}{g}$.

04. Show that the maximum height reached by a projectile launched at an angle of 45° is one quarter of its range. TS Mar 14

Ans: Let a projectile be thrown into air at an angle 'θ' above the horizontal with velocity 'u', its maximum height during the motion is $H = \frac{u^2 \sin^2\theta}{2g}$ —— (1)

Its horizontal range is $R = \frac{u^2 \sin 2\theta}{g}$ —— (2)

Dividing equation (1) by equation (2), $\frac{H}{R} = \frac{u^2 \sin^2\theta}{2g} \times \frac{g}{u^2 \sin 2\theta} = \frac{\sin^2\theta}{2 \times 2\sin\theta\cos\theta} \Rightarrow \frac{H}{R} = \frac{\tan\theta}{4}$

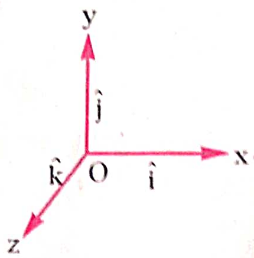
$\therefore 4H = R\tan\theta$ —— (3)

In the question, given that $\theta = 45°$, $\therefore 4H = R\tan 45° = R \times 1 = R \Rightarrow H = \frac{R}{4}$.

Thus, maximum height reached is one quarter of its range.

05. Define unit vector, null vector and position vector. AP May 97, Sep 2000, May 22, June 15

Ans: **Unit Vector:** A vector whose magnitude is unity (1) is called unit vector.



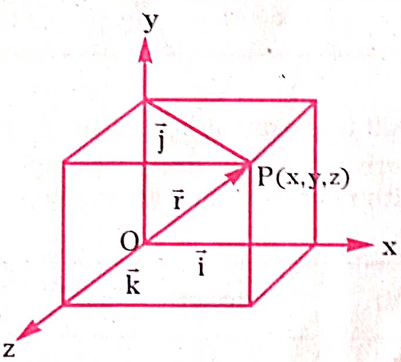
For a given vector $\vec{A}$, it is represented by $\hat{A}$.

The unit vector along the direction of $\vec{A}$ is given by $\hat{A} = \frac{\vec{A}}{|\vec{A}|}$.

It has no units and dimensions.

Eg: In a coordinate system, $\hat{i}$, $\hat{j}$, $\hat{k}$ are the unit vectors along X, Y & Z axis respectively (or) $|\hat{i}| = |\hat{j}| = |\hat{k}| = 1$.

Null Vector: A vector whose magnitude is zero(0) is called a null vector. It is represented by $\vec{O}$ as shown in the figure.



Eg: The position of a particle at the origin.

Position vector: A vector which specifies the position of an object with respect to the origin of a coordinate system is called as position vector of the object in the system.

The position vector of an object at P is represented by $\overline{OP}$ as shown in the figure.

Eg: If P(x,y,z) are the coordinates of the object P and O is the origin of the system, then position vector is given by $\overline{OP} = x\hat{i} + y\hat{j} + z\hat{k}$.

Its magnitude $|\overline{OP}| = \sqrt{x^2 + y^2 + z^2}$.

06. **If $|\vec{a}+\vec{b}|=|\vec{a}-\vec{b}|$, prove that the angle between $\vec{a}$ and $\vec{b}$ is $90°$.** TS Mar & May 18, May 22

Ans: Let 'θ' be the angle between $\vec{a}$ and $\vec{b}$.

Given that, $|\vec{a}+\vec{b}|=|\vec{a}-\vec{b}| = \sqrt{a^2+b^2+2ab\cos\theta} = \sqrt{a^2+b^2-2ab\cos\theta}$

squaring on both sides,

$a^2+b^2+2ab\cos\theta = a^2+b^2-2ab\cos\theta \Rightarrow 4ab\cos\theta = 0 \Rightarrow \cos\theta = 0 \Rightarrow \theta = 90°$.

Hence, angle between the two vectors is $90°$.

07. **A bird holds a fruit in its beak and flies parallel to the ground. It lets go of the fruit at some height. Describe the trajectory of the fruit as it falls to the ground as seen by a) the bird b) a person on the ground.** TS May 22

Ans: When the bird dropped a fruit while flying horizontally, it falls on to the ground after some time. The path travelled by fruit depends on the reference frame.

a) At any time 't', the horizontal and vertical components of velocity of the bird and the fruit will be as below:

Fruit	Bird	Fruit with respect to the bird
$u_x = u$	$u_x = u$	$u_x = u - u = 0$
$u_y = 0$	$u_y = 0$	$u_y = 0$
$a_x = 0$	$a_x = 0$	$a_x = 0$
$a_y = g$	$a_y = g$	$a_y = g - g = 0$
$y = \frac{1}{2}gt^2$	$y = 0$	$y = \frac{1}{2}gt^2 - 0 = \frac{1}{2}gt^2$
$x = ut$	$x = ut$	$x = ut - ut = 0$

Hence, the path of the fruit is a straight line vertically downwards with respect to the bird.

b) If we take stationary person on the ground as reference, then horizontal and vertical displacements of fruit with respect to person will be as below:

Fruit	Person	Fruit with respect to the person
$u_x = u$	$u_x = 0$	$u_x = u - u = 0$
$u_y = 0$	$u_y = 0$	$u_y = 0$
$a_x = 0$	$a_x = 0$	$a_x = 0$
$a_y = g$	$a_y = 0$	$a_y = g - 0 = g$
$y = \frac{1}{2}gt^2$	$y = 0$	$y = \frac{1}{2}gt^2 - 0 = \frac{1}{2}gt^2$
$x = ut$	$x = 0$	$x = ut - 0 = ut$ and $t = \frac{x}{u}$

$$y_{fp} = u_y t + \frac{1}{2}gt^2 = 0 + \frac{1}{2}g\left(\frac{x}{u}\right)^2 = \frac{1}{2}\frac{gx^2}{u^2}.$$

Put $\frac{g}{2u^2} = A$ (constant).

$\therefore$ $y = Ax^2$. It is the displacement in two dimensional motion.

Result: Hence, the path of the fruit is a parabola with respect to the person.

08. A force $2\hat{i} + \hat{j} - \hat{k}$ newton acts on a body which is initially at rest. At the end of 20 secs, the velocity of the body is $4\hat{i} + 2\hat{j} - 2\hat{k}\ ms^{-1}$. What is the mass of the body ? **AP May 16**

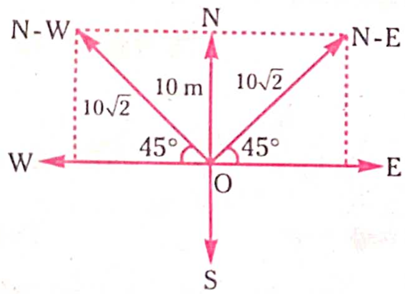
Ans: Force acting on the body $\vec{F} = m\vec{a} = m\left(\frac{\vec{v} - \vec{u}}{t}\right)$.

Given that initial velocity $\vec{u} = 0$, final velocity $\vec{v} = 4\hat{i} + 2\hat{j} - 2\hat{k}$, time $t = 20\,s$.

Force, $\vec{F} = 2\hat{i} + \hat{j} - \hat{k}N \Rightarrow |2\hat{i} + \hat{j} - \hat{k}| = m\left|\frac{4\hat{i} + 2\hat{j} - 2\hat{k}}{20}\right| \Rightarrow |2\hat{i} + \hat{j} - \hat{k}| = \frac{2m}{20}|2\hat{i} + \hat{j} - \hat{k}| \Rightarrow m = \frac{20}{2} = 10\,kg$.

09. 'O' is a point on the ground choosen as origin. A body first suffers a displacement $10\sqrt{2}$ m North - East, next 10 m North and finally $10\sqrt{2}$ m North - West. How far it is from the origin? **TS Mar 19; SOLVED PROBLEM**

Ans:



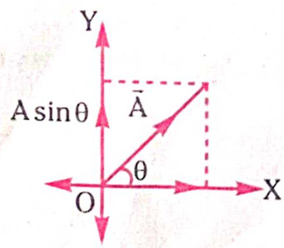
$\vec{S}_1 = 10\sqrt{2}$ m due N - E $= (10\hat{i} + 10\hat{j})$m , $\vec{S}_2 = 10$ m due N $= 10\hat{j}$,

$\vec{S}_3 = 10\sqrt{2}$ m due N - W $= -10\hat{i} + 10\hat{j}$.

$\vec{S}_1 + \vec{S}_2 + \vec{S}_3 = 10\hat{i} + 10\hat{j} + 10\hat{j} - 10\hat{i} + 10\hat{j} = 30\hat{j} = 30$ m due north.

VERY SHORT ANSWER QUESTIONS (2 MARKS)

10. The vertical component of a vector is equal to its horizontal component. What is the angle made by the vector with X-axis ? **TS May 18; AP Mar 19**



Ans: Consider a vector $\vec{A} = A_x\hat{i} + A_y\hat{j}$.

Let 'θ' be the angle made by $\vec{A}$ with X-axis.

X-component of $\vec{A} = A_x = A\cos\theta$, Y-component of $\vec{A} = A_y = A\sin\theta$.

Given that, $A_x = A_y \Rightarrow A\cos\theta = A\sin\theta \Rightarrow \tan\theta = 1 \Rightarrow \theta = 45°$.

11. Two forces of magnitudes 3 units and 5 units act at 60° with each other. What is the magnitude of their resultant ? AP Mar 15, 17, May 16, 17; TS May 22

Ans: Magnitude of the resultant, $F_R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$.

$F_R = \sqrt{(3)^2 + (5)^2 + 2\times3\times5\cos 60^\circ} = \sqrt{9+25+2\times3\times5\times(1/2)} = \sqrt{49} = 7$ units.

12. When two right angled vectors of magnitude 7 units and 24 units combine, what is the magnitude of their resultant ? May 14; AP Mar 16, 18, May 18

Ans: Given that the angle between the two vectors is 90°.

Magnitude of their resultant, $F_R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$.

$F_R = \sqrt{(7)^2 + (24)^2 + 2\times7\times24\cos 90^\circ} = \sqrt{49+576} = \sqrt{625} = 25$ units.

13. $\vec{A} = \hat{i} + \hat{j}$. What is the angle between the vector and X-axis ? AP Mar 13, 14, 20, May 22; TS Mar 17, 20

Ans: Given, $\vec{A} = \hat{i} + \hat{j}$. Compare it with $\vec{A} = A_x\hat{i} + A_y\hat{j}$.

Let 'α' be the angle made by the vector $\vec{A}$ with x-axis.

Then $\cos\alpha = \frac{A_x}{|\vec{A}|} = \frac{1}{\sqrt{1^2+1^2}} = \frac{1}{\sqrt{2}} \Rightarrow \theta = 45^\circ$.

14. If $\vec{P} = 2\hat{i} + 4\hat{j} + 14\hat{k}$ and $\vec{Q} = 4\hat{i} + 4\hat{j} + 10\hat{k}$, then find the magnitude of $\vec{P} + \vec{Q}$. TS Mar 15, 16, May 22

Ans: $\vec{P} + \vec{Q} = (2\hat{i} + 4\hat{j} + 14\hat{k}) + (4\hat{i} + 4\hat{j} + 10\hat{k}) = 6\hat{i} + 8\hat{j} + 24\hat{k}$.

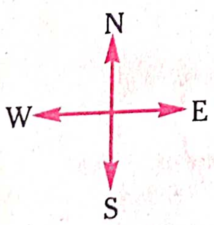
Magnitude of $\vec{P} + \vec{Q}$ is given by $|\vec{P} + \vec{Q}| = \sqrt{(6)^2 + (8)^2 + (24)^2} = \sqrt{36+64+576} = \sqrt{676} = 26$ units.

15. What is the acceleration of a projectile at the top of its trajectory ? TS Mar 19

Ans: Acceleration of a projectile at the top of its trajectory is 'g' (acceleration due to gravity) and directed vertically downwards $(a = g\downarrow)$.

16. Wind is blowing from the south at $5\ ms^{-1}$. To a cyclist, it appears to be blowing from the east at $5\ ms^{-1}$. Find the velocity of the cyclist. SOLVED PROBLEM

Ans:



Velocity of wind, $\vec{v}_w = 5\hat{j}$, Velocity of wind relative to cyclist, $\vec{v}_{wc} = -5\hat{i}$.

$\therefore\ \vec{v}_{wc} = \vec{v}_w - \vec{v}_c \Rightarrow \vec{v}_c = \vec{v}_w - \vec{v}_{wc} = 5\hat{j} - (5\hat{i}) = +5\hat{j} + 5\hat{i} = |\vec{v}_c| = 5\sqrt{2}\ ms^{-1}$ towards north east.

THE END

05 Laws of Motion

LAQ (0) - 0 × 8 = 0M	
SAQ (1) - 1 × 4 = 4M	
VSAQ(1) - 1 × 2 = 2M	
Total Marks	= 6M

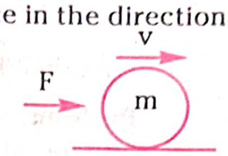
LONG ANSWER QUESTIONS (8 MARKS)

01. i) State newton's second law of motion. Hence derive the equation of motion F = ma from it.
AP Mar 16, 17, 19, May 16, 17

ii) A body is moving along a circular path such that its speed always remains constant. Should there be a force acting on the body ?

Ans: i) **Newton's second law of motion:** 'The rate of change of momentum of a body is directly proportional to the net external force acting on the body and it takes place in the direction of the force that acts'.

Derivation:



Consider a body of mass 'm' moving with velocity 'v'. Let a net external force 'F' acts on the body. Let its velocity is increased by Δv in a time interval Δt.

According to newton's II law of motion $F \propto \frac{\Delta p}{\Delta t}$ (or) $F = k\left(\frac{\Delta p}{\Delta t}\right)$,

where 'k' is proportionality constant.

At a particular instant, $F = k\left(\underset{\Delta t \to 0}{Lt} \frac{\Delta p}{\Delta t}\right) = k\left(\frac{dp}{dt}\right)$ (or) $F = k\frac{d(mv)}{dt}$. [$\because$ Momentum $P = mv$]

As mass of the body is constant, $F = km\frac{dv}{dt} = kma$ $\left(\because \frac{dv}{dt} = \text{acceleration (a)}\right)$

If, $k = 1$, then $F = ma$. If $m = 1\,kg$, $a = 1\,ms^{-2}$, then $F = 1\,N$.

SI unit of force is 'N' (or) $kg\,ms^{-2}$. CGS unit is dyne (or) $g\,cms^{-2}$.

Dimensional formula $[MLT^{-2}]$.

ii) Yes, centripetal force must act on the body.

SHORT ANSWER QUESTIONS (4 MARKS)

02. Mention the methods used to decrease friction.
AP Mar & May 14; AP Mar & May 18; May 22; TS Mar 16, 19, May 16, 17

Ans: 1) **Polishing:** When surfaces are polished, irregularities of the surfaces are minimised thereby friction decreases.

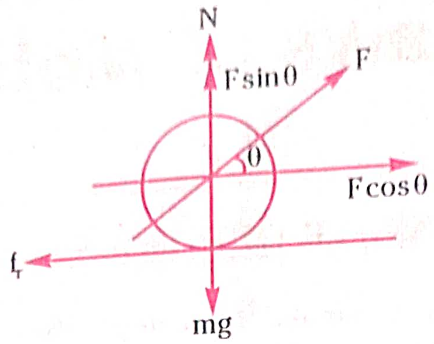
2) **Ball-Bearings:** The hard steel balls (call bearing) placed between the moving parts convert sliding friction into rolling friction, hence, friction is reduced.

3) **Lubricants:** Lubricants like oil (or) grease which spreads over the surface and fills the irregularities of the surface, thereby, the friction is reduced.

4) **Streamlining:** By making front portion of vehicles in a curved shape friction due to air can be reduced.

03. Why pulling the lawn roller is preferred than pushing the lawn roller ?
AP Mar 06, 08, 10, June 10

Ans: **Pulling:** Consider a lawn roller pulled by a force 'F' which makes an angle 'θ' with the horizontal. The weight 'mg' acts vertically downwards and normal reaction 'N' acts vertically upwards as shown in figure.

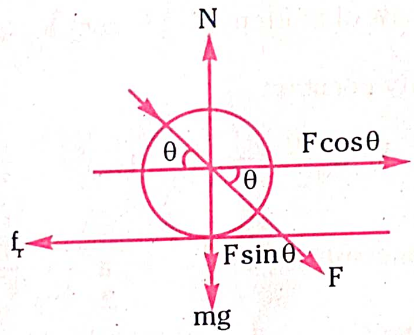


Let force 'F' be resolved into two components. The component $F\sin\theta$ acts vertically upwards and other component $F\cos\theta$ acts along horizontal direction.

In this case, normal reaction, $N = mg - F\sin\theta$

Frictional force, $f_r = \mu_r N$ (or) $f_r = \mu_r(mg - F\sin\theta)$ ——— (1)

Pushing: Suppose the lawn roller is pushed by a force 'F' which makes an angle 'θ' with the horizontal. The weight 'mg' acts vertically downwards and normal reaction 'N' acts vertically upwards as shown in figure.



Let the force 'F' be resolved into two components. The component $F\sin\theta$ acts vertically downwards and other component $F\cos\theta$ acts along horizontal direction.

In this case,

Normal reaction, $N = mg + F\sin\theta$

Frictional force, $f_r = \mu_r N \Rightarrow f_r = \mu_r(mg + F\sin\theta)$ ——— (2)

From eq. (1) and (2), we see that the frictional force is more in pushing than in pulling case.

Hence, it is easier to pull than to push a lawn roller.

04. Explain the advantages and the disadvantages of friction ?

AP Mar 06, 15; TS Mar 15, 17, May 22

Ans: **Advantages of Friction:**

1) One can hold any object with fingers due to friction.
2) Safe walking on the floor is possible because of friction between the floor and the feet.
3) Nails and screws are fitted in the walls (or) wooden surfaces due to friction.
4) A match stick is lightened because of friction.

Disadvantages of friction:

1) Due to friction wear and tear of machines increases.
2) Heat generated due to friction, decreases the efficiency of engine.
3) Friction results in the large amount of power loss in engines.

05. Define the terms momentum and impulse. State and explain the law of conservation of linear momentum. Give its examples. AP Mar 20; TS June 15, May 18

Ans: **Momentum:** The momentum (p) of a body is defined as the product of its mass (m) and velocity (v).

$\bar{p} = m\bar{v}$.

Impulse: 'It is defined as finite change in momentum during small interval of time'. (or)

Impulse = force × time interval

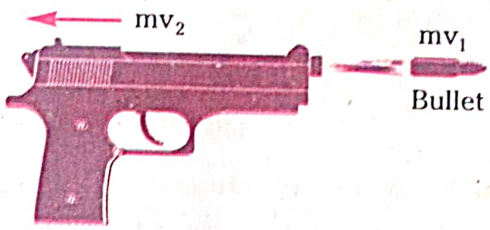
$\bar{J} = m\bar{v} - m\bar{u} = \bar{F}\Delta t$.

Law of conservation of linear momentum: It states that 'the total momentum of an isolated system remains constant if there is no net external force acting on it'.

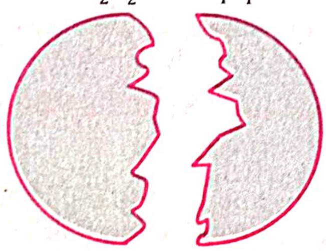
Examples:

1) According to law of conservation of momentum, the total momentum of the bullet and the gun before and after firing should be the same. In this case it is equal to zero. So, as the bullet gets forward momentum, the gun should get equal momentum in backward direction.

$p_b + p_g = 0 \Rightarrow p_b = -p_g$.



2) **Explosion of a bomb into two pieces:**



Bomb is initially at rest. So initial momentum of the bomb $= 0$.

According to law of conservation of linear momentum,

initial momentum of the bomb = final momentum of the two pieces of the bomb

$0 = m_1v_1 + m_2v_2 \Rightarrow m_1v_1 = -m_2v_2$ i.e., $p_1 = -p_2$.

Hence, the two parts fly off in opposite directions.

3) **Motion of a rocket:** When a rocket is fired the exhaust gases of the fuel release downwards, then the rocket moves upwards with equal and opposite momentum.

06. State the laws of rolling friction. TS Mar 20, May 22

Ans: The laws of rolling friction can be stated as follows:

1) The rolling friction is directly proportional to the normal reaction.
2) Rolling friction depends upon area of contact.
3) Rolling friction depends upon radius of rolling body.

VERY SHORT ANSWER QUESTIONS (2 MARKS)

07. **What is inertia ? What gives the measure of inertia ?** AP Mar 14, 19, TS Mar 17

Ans: 1) The inability of a body to change its state of rest or state of motion by itself is known as inertia.

2) Mass is a measure of inertia.

08. **When a bullet is fired from a gun, the gun gives a kick in the backward direction. Explain.** Mar 15

Ans: According to law of conservation of momentum, the total momentum before and after firing should be the same. Here, total momentum of the gun and the bullet before firing is equal to zero. After firing as the bullet gets forward momentum, the gun should get equal momentum in backward direction for total momentum zero.

09. **If a bomb at rest explodes into two pieces, the pieces must travel in opposite directions. Explain.** TS Mar 15, 16, May 22, June 15

Ans: Bomb is initially at rest. So, initial momentum of the bomb $=0$.

According to the law of conservation of linear momentum,

Initial momentum of the bomb = total final momentum of the two pieces of the bomb

i.e., $0=m_1v_1+m_2v_2 \Rightarrow m_1v_1=-m_2v_2 \Rightarrow v_2=-\left(\frac{m_1}{m_2}\right)(v_1)$.

Hence, the two parts fly off in opposite directions.

10. **Can the coefficient of friction be greater than one ?** TS Mar 18

Ans: Yes, when the contact surfaces are polished heavily, then the adhesive forces between the molecules increases, then the value of coefficient of friction will be greater than unity.

11. **Why does the car with a flattened tyres stop sooner than the one with inflated tyres ?** AP Mar 20, May 11

Ans: Rolling friction depends on area of contact. In the case of flattened tyres, the rolling friction is more due to greater deformation of tyres. As friction is more, it stops sooner.

12. **A horse has to pull harder during the start of the motion than later. Explain ?** AP Mar 13, 18, May 09, 16, 22

Ans: Before starting the motion, a horse experiences limiting friction and later it experiences kinetic friction. Limiting friction is more than kinetic friction. Thus, the horse has to pull a cart harder during the start of the motion than later.

13. **What happens to coefficient of friction if weight of the body is doubled ?** AP May 14, Mar 16; TS Mar 19, May 22

Ans: Coefficient of friction depends only on nature of the surfaces in contact and independent of weight of the body. So, it remains constant.

14. **Calculate the time needed for a net force of 5N to change the velocity of a 10 kg mass by $2\ ms^{-1}$.** TS May 16; SOLVED PROBLEM

Ans: Given, force, $F_{net}=5\,N$, mass, $m=10\,kg$

Change in velocity $(\Delta v)=2\,ms^{-1}$, time $t=?$

$$F_{net}=ma=m\left(\frac{\text{Change in velocity}}{\text{time}}\right)=\frac{m(\Delta v)}{t} \Rightarrow 5=\frac{10(2)}{t} \Rightarrow t=4\,s.$$

15. A constant force acting on a body of mass 3.0 kg changes its speed from $2.0\ ms^{-1}$ to $3.5\ ms^{-1}$ in 25 sec. The direction of motion of the body remains unchanged. What is the magnitude and direction of the force ?

ADD. PROBLEM

Ans: Here, $m = 3.0\ kg$, $u = 2.0\ ms^{-1}$, $v = 3.5\ ms^{-1}$, $t = 25\ s$, $F = ?$

$$F = ma = \frac{m(v-u)}{t} = \frac{3.0(3.5-2.0)}{25} = 0.18\ N.$$

The force is along the direction of motion.

16. A batsman hits back a ball straight in the direction of the bowler without changing its initial speed of $12\ ms^{-1}$. If the mass of the ball is $0.15\ kg$, determine the impulse imparted to the ball. (Assume linear motion of the ball)

AP Mar 17; TS Mar 20; EXAMPLE PROBLEM

Ans: Change in momentum $= 0.15 \times 12 - (-0.15 \times 12) = 3.6\ Ns$.

Impulse $= 3.6\ Ns$, in the direction from the batsman to the bowler.

This is an example where the force on the ball by the batsman and the time of contact of the ball and the bat are difficult to know, but the impulse is readily calculated.

THE END

06 Work, Energy and Power

LAQ (1)	- 1 × 8 = 8M
SAQ (0)	- 0 × 4 = 0M
VSAQ(0)	- 0 × 2 = 0M
Total Marks	= 8M

LONG ANSWER QUESTIONS (8 MARKS)

01. a) State the law of conservation of energy and verify it in case of a freely falling body. What are the conditions under which the law of conservation of energy is applicable ?

AP June 15, Mar 15, 16, 18, May 16, 18; TS June 15, Mar 16, 17, 19, 20, May 16, 17, 18

b) A machine gun fires 360 bullets per minute and each bullet travels with a velocity of $600\ ms^{-1}$. If the mass of each bullet is 5 gm, then find the power of the machine gun ?

Mar 14; AP June 15, May 16, Mar 16, 18; TS May 18; PROBLEM

Ans: a) **Law of conservation of mechanical energy:**

Statement: 'The total mechanical energy of a system is constant, if the internal forces doing work on it are conservative and the external forces do no work'.

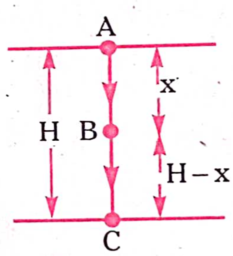
Verification in the case of freely falling body:

Consider a ball of mass 'm' dropped freely from a height 'H'.

The total mechanical energy of the ball 'E' is given by $E = K + U$ where 'K' is the kinetic energy, 'U' is the potential energy of the ball. Let A, B, C be the points at a height 'H', H-x and on the ground respectively as shown in the figure.

At A:

Height of the ball $= H$, Velocity of the ball $= v_A = 0$, Distance travelled by the ball $= 0$.



Kinetic energy of the ball, $K = \frac{1}{2}mv_A^2 = \frac{1}{2}m(0)^2 = 0$

Potential energy of the ball, $u = mgH$

The total energy at 'A' is $E_A = K + U$

$E_A = 0 + mgH \Rightarrow E_A = mgH$ —— (1)

At B:

Height of the ball $= H - x$, Velocity of the ball $= v_B$, Distance travelled by the ball $= x$

From $v_B^2 - v_A^2 = 2as$; $v_B^2 - 0^2 = 2gx \Rightarrow v_B^2 = 2gx$

The kinetic energy of the ball, $K = \frac{1}{2}mv_B^2 = \frac{1}{2}m(2gx) = mgx$.

The potential energy of the ball, $U = mg(H - x) = mgH - mgx$.

The total energy of the ball, $E_B = U + K$

$E_B = mgH - mgx + mgx \Rightarrow E_B = mgH$ —— (2)

At C:

Height of the ball $= 0$, Velocity of the ball $= v_C$, Distance travelled by the ball $= H$

From $v_C^2 - v_A^2 = 2as$,

$v_C^2 - 0^2 = 2gH \Rightarrow v_C^2 = 2gH$

Kinetic energy of the ball, $K = \frac{1}{2}mv_C^2 = \frac{1}{2}m(2gH) = mgH$

Potential energy of the ball, $U = mgh = 0 \quad (\because h = 0)$

The total energy of the ball, $E_C = K + U$

$E_C = mgH + 0 \Rightarrow E_C = mgH$ —— (3)

From equations (1), (2) and (3) it can be concluded that the total mechanical energy of the ball remains constant under the action of gravitational force which is a conservative force.

Conditions:

1) The total mechanical energy of the system remains constant, under the action of the conservative forces.
2) The total mechanical energy of the system is not constant, under the action of non-conservative forces.

b) Let velocity of each bullet be $v = 600\ ms^{-1}$, Power $= ?$

Mass of each bullet, $m = 5\ gm = 5\times10^{-3}$ kg, No. of bullets fired, $n = 360$, Time, $t = 1$ min $= 60$ s.

Power, $P = \frac{1}{2}\frac{mnv^2}{t} = \frac{1}{2}\times\frac{0.005\times360\times600\times600}{60} = 5400\ W = 5.4\ kW$.

02. Develop the notions of work and kinetic energy and show that it leads to work-energy theorem.
AP Mar 14, 15, 17, May 17; TS Mar 15, May 22

Ans: **Work:** Work is said to be done by a force when a body undergoes displacement parallel to the line of action of the force.

$W = \bar{F}\cdot\bar{S} = FS\cos\theta$

Kinetic energy: Kinetic energy is defined as the energy possessed by a body by virtue of its motion.

$K.E = \frac{1}{2}mv^2$

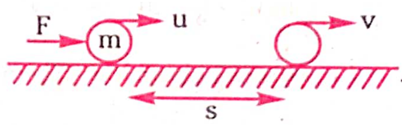
Eg: i) A vehicle in motion, ii) Water flowing in river etc.

Work energy theorem:

Statement: The work done on a particle by a resultant force is equal to the change in its kinetic energy.

Proof: Consider a particle of mass 'm' moving with an initial velocity 'u'. When a constant resultant force 'F' acts on it, it moves with uniform acceleration 'a' and attains velocity 'v' after 't' sec. Let 's' be the displacement of the particle.

From equations of motion, $v^2 - u^2 = 2as$



Multiplying the above equation with $\frac{m}{2}$ on both sides,

$\frac{m}{2}[v^2 - u^2] = \frac{m}{2}(2as) \Rightarrow \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mas \Rightarrow \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$. Here work done, $W = Fs$

$\Rightarrow \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = W$.

The above equation gives relation between work and kinetic energy.

(or) $K_f - K_i = W$,

where K_i and K_f are the initial and final kinetic energies of the object respectively.

03. a) What are collisions ? Explain the possible types of collisions ? Develop the theory of one dimensional elastic collision. May 14, AP Mar 19, 20; TS Mar 18, TS May 22

b) Show that in the case of one dimensional elastic collision, the relative velocity of approach of two colliding bodies before collision is equal to the relative velocity of separation after collision.

c) A body freely falling from a certain height 'h', after striking a smooth floor rebounds and raises to a height 'h / 2'. What is the coefficient of restitution between the floor and the body? TS Mar 18

Ans: a) A strong interaction between bodies which involves exchange of momenta is called collision. They are of two types: 1) Elastic collision, 2) Inelastic collision

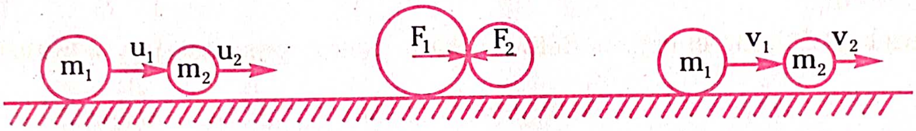
Elastic collision: The collisions in which both momentum and kinetic energy are conserved are known as elastic collisions.

Inelastic collisions: The collisions in which kinetic energy is not conserved but momentum is conserved are known as inelastic collisions. Here the loss of kinetic energy appears in the form of heat or other forms of energy.

Perfectly inelastic collisions: When two bodies move together after collision, the collision is said to be perfectly inelastic.

One dimensional elastic collision: If the velocities of the objects involved in collision are along the same straight line before and after collisions, then such collisions are known as one dimensional collisions.

Consider two smooth spheres moving along a straight line joining their centres. Let m_1 and m_2 are the masses of the two bodies. Suppose they undergo one dimensional elastic collision. Before collision, let u_1 and u_2 be their velocities. After collision, let v_1 and v_2 be their final velocities. Assume that $u_1 > u_2$.



a) Before collision b) During collision c) After collision

From the law of conservation of linear momentum,

Momentum of the system before collision = Momentum of the system after collision

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2 \Rightarrow m_1(u_1 - v_1) = m_2(v_2 - u_2) \quad \text{—— (1)}$$

In case of elastic collision, kinetic energy is also conserved.

Hence, K.E of the system before collision = K.E of the system after collision

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 \Rightarrow m_1(u_1^2 - v_1^2) = m_2(v_2^2 - u_2^2) \quad \text{—— (2)}$$

Dividing equation (2) by (1), we get

$$\frac{u_1^2 - v_1^2}{u_1 - v_1} = \frac{v_2^2 - u_2^2}{v_2 - u_2} \Rightarrow \frac{(u_1 + v_1)(u_1 - v_1)}{(u_1 - v_1)} = \frac{(v_2 + u_2)(v_2 - u_2)}{(v_2 - u_2)}$$

$$u_1 + v_1 = v_2 + u_2 \Rightarrow u_1 - u_2 = v_2 - v_1 \quad \text{—— (3)}$$

Hence, relative velocity of approach before collision = relative velocity of separation after collision.

From equation (3), we get $v_2 = u_1 - u_2 + v_1$ —— (4)

Substituting equation (4) in equation (1), we get

$$m_1(u_1 - v_1) = m_2(u_1 - u_2 + v_1 - u_2) \Rightarrow m_1u_1 - m_1v_1 = m_2u_1 + m_2v_1 - 2m_2u_2$$

$$\Rightarrow v_1(m_1+m_2)=u_1(m_1-m_2)+2m_2u_2 \Rightarrow v_1=\left(\frac{m_1-m_2}{m_1+m_2}\right)u_1+\left(\frac{2m_2}{m_1+m_2}\right)u_2 \quad \text{——— (5)}$$

Again, from equation (3), we get $v_1=v_2+u_2-u_1$

Substituting v_1 in equation (1), we get

$$m_1(u_1-v_2-u_2+u_1)=m_2(v_2-u_2) \Rightarrow 2m_1u_1-m_1u_2-m_1v_2=m_2v_2-m_2u_2$$

$$\Rightarrow (m_1+m_2)v_2=2m_1u_1+(m_2-m_1)u_2$$

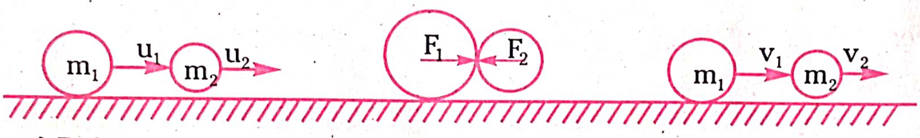
$$\Rightarrow v_2=\left(\frac{m_2-m_1}{m_1+m_2}\right)u_2+\left(\frac{2m_1}{m_1+m_2}\right)u_1 \quad \text{——— (5)}$$

From equations (4) and (5), it is concluded that the final velocities of both the bodies depend on their initial velocities and masses.

b) 'If the velocities of the objects involved in collision are along the same straight line before and after collision, then such collisions are known as one dimensional collisions'.

Consider two smooth spheres that are non-rotating and moving along a straight line joining their centres. Let their masses be m_1 and m_2. They undergo one dimensional elastic collision.

Before collision, let their velocities be u_1 and u_2. After collision, let their final velocities be v_1 and v_2 respectively. Assume that $u_1>u_2$.



a) Before collision b) During collision c) After collision

In elastic collision, both momentum and kinetic energy are conserved.

From the law of conservation of linear momentum,

momentum of the system before collision = momentum of the system after the collision

$$m_1u_1+m_2u_2=m_1v_1+m_2v_2 \Rightarrow m_1(u_1-v_1)=m_2(v_2-u_2) \quad \text{——— (1)}$$

From the law of conservation of K.E,

K.E of the system before collision =K.E of the system after collision

$$\frac{1}{2}m_1u_1^2+\frac{1}{2}m_2u_2^2=\frac{1}{2}m_1v_1^2+\frac{1}{2}m_2v_2^2 \Rightarrow m_1(u_1^2-v_1^2)=m_2(v_2^2-u_2^2) \quad \text{——— (2)}$$

Dividing equation (2) by (1), we get

$$\frac{u_1^2-v_1^2}{u_1-v_1}=\frac{v_2^2-u_2^2}{v_2-u_2} \Rightarrow \frac{(u_1+v_1)(u_1-v_1)}{(u_1-v_1)}=\frac{(v_2+u_2)(v_2-u_2)}{(v_2-u_2)}$$

$$u_1+v_1=v_2+u_2 \Rightarrow u_1-u_2=v_2-v_1 \quad \text{——— (3)}$$

Hence, $\begin{pmatrix}\text{relative velocity of approach}\\ \text{before collision}\end{pmatrix}=\begin{pmatrix}\text{relative velocity of approach}\\ \text{after collision}\end{pmatrix}$.

c) $e=\sqrt{\frac{h_2}{h_1}}$, $h_2=\frac{h}{2}$ and $h_1=h$, $e=\sqrt{\frac{h/2}{h}}=\frac{1}{\sqrt{2}}$.

SHORT ANSWER QUESTIONS (4 MARKS)

04. A pump is required to lift 600 kg of water per minute from a well 25 m deep and to eject it with a speed of $50\ ms^{-1}$. Calculate the power required to perform the above task ?

AP Mar 15, June 15, May 18; TS Mar 16, 19, 20; May 22 ; PROBLEM

Ans: Mass of water that has to be lifted is $M = 600\ kg$, Height to be lifted, $h = 25\ m$, $g = 10\ ms^{-2}$,

Velocity of ejection $= 50\ ms^{-1}$, time $= 60\ sec$.

Power, $P = \frac{Mgh + (1/2)Mv^2}{t} = \frac{600 \times 10 \times 25 + (1/2) \times 600 \times 50 \times 50}{60} = 15000\ W = 15\ KW$.

THE END

07 System of Particles & Rotational Motion

LAQ (0) - 0 × 8 = 0M	
SAQ (2) - 2 × 4 = 8M	
VSAQ(0) - 0 × 2 = 0M	
Total Marks = 8M	

LONG ANSWER QUESTIONS (8 MARKS)

01. State and prove the principle of conservation of angular momentum. Explain the principle of conservation of angular momentum with examples. AP Mar 08, 16

Ans: **Law of conservation of angular momentum:**

Statement: If there is no resultant external torque acting on a rotating system, then angular momentum of the system remains constant both in magnitude and direction.

Proof: When a torque 'τ' acts on a rotating system, then its angular momentum 'L' is given by $\tau = \frac{dL}{dt}$. If the resultant external torque 'τ' is equal to zero then,

$$\frac{dL}{dt} = 0 \Rightarrow L = \text{constant}$$

$$\Rightarrow I\omega = \text{constant} \Rightarrow I_1\omega_1 = I_2\omega_2$$

Examples:

i) A man stands on a turn table with dumbbells in his stretched hands. The turn table is set into rotation at a constant angular velocity 'ω'.

a) If the man brings his hands closer to his body, moment of inertia decreases and angular velocity increases.

b) If the man stretches his hands away from his body, moment of inertia increases and angular velocity decreases.

Here, $L =$ constant. i.e, $I\omega =$ constant (or) $\omega \propto \frac{1}{I}$.

ii) a) A ballet dancer decreases his angular velocity by increasing his moment of inertia by stretching his hands. ($\because I\omega = \text{constant}$)

b) A ballet dancer increases his angular velocity by decreasing his moment of inertia by bringing his hands closer to the body.

iii) a) When a planet comes closer to the sun, its moment of inertia decreases and its angular velocity increases. ($\because I\omega =$ constant)

b) When a planet moves away some distance from the sun its moment of inertia increases and its angular velocity decreases.

iv) For a helicopter, the rotor of the main propeller at the top starts rotating in one direction, then another propeller provided at its tail starts rotating in opposite direction. In this way the law of conservation of angular momentum is maintained. So, a helicopter is provided with two propellers.

SHORT ANSWER QUESTIONS (4 MARKS)

02. Distinguish between centre of mass and centre of gravity.

AP Mar 13, 14, 15, 16, 17, 18, June 15, May 17, 22; TS Mar 15, 16, May 17, 18

Ans:

Centre of mass	Centre of gravity
1) The centre of mass of a body is the point, where the entire mass is supposed to be concentrated.	The centre of gravity of a body is the point, through which weight of the body always acts.
2) It is defined to describe the nature of motion of the body.	It is defined to know the stability of the body.
3) It refers to the mass of the body.	It refers to the weight of the body.
4) In case of small and regular bodies, centre of mass and centre of gravity will coincide.	In case of larger bodies, centre of gravity will not coincide with centre of mass
5) It does not depend on acceleration due to gravity.	It depends on acceleration due to gravity

03. Define angular acceleration and torque. Establish the relation between angular acceleration and torque. **AP June 15, Mar 19; TS Mar 17, 18, 20, May 17, June 15**

Ans: **Angular acceleration (α) :** The rate of change of angular velocity of a particle is called angular acceleration, i.e., $\alpha = \frac{d\omega}{dt}$.

Torque (τ): The rate of change of angular momentum is called torque, $\tau = \frac{dL}{dt}$.

Relation between angular acceleration and torque: The rate of change of angular momentum of a body is equal to the external torque acting on it. Consider a body rotating about a fixed axis passing through a point due to an external torque 'τ'.

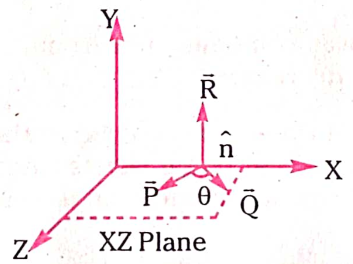
According to Newton's second law, $\tau = \frac{dL}{dt} = \frac{d}{dt}(I\omega)$ $[\therefore L = I\omega]$

$\tau = I\frac{d\omega}{dt} = I\alpha$ $\left[\because \alpha = \frac{d\omega}{dt}\right]$ $\therefore \tau = I\alpha$.

04. Define vector product. Explain the properties of a vector product with two examples.

AP Mar 15, 17, 20, May 17, 18, 22; TS Mar 15, 16, 17, May 16, 18

Ans: **Vector Product (or) Cross Product:** The vector product of any two vectors is equal to the product of the magnitude of the two vectors and the sine of the angle between them and the resultant direction is always perpendicular to plane formed by the two vectors.



Vector product between two vectors $\vec{P}$ and $\vec{Q}$ can be expressed as $\vec{P}\times\vec{Q} = PQ\sin\theta\hat{n} = \vec{R}$.

where $\hat{n}$ is a unit vector normal to the plane formed by $\vec{P}$ and $\vec{Q}$.

The magnitude of $\vec{R}$ is given by $R = PQ\sin\theta$.

Properties of vector product:

i) Cross product of vectors does not obey commutative law.

$\vec{P}\times\vec{Q} \neq \vec{Q}\times\vec{P}$ but $\vec{P}\times\vec{Q} = -(\vec{Q}\times\vec{P})$.

ii) Cross product obeys distributive law over addition and subtraction.

$\vec{P}\times(\vec{Q}-\vec{R}) = (\vec{P}\times\vec{Q})-(\vec{P}\times\vec{R})$, $\vec{P}\times(\vec{Q}+\vec{R}) = (\vec{P}\times\vec{Q})+(\vec{P}\times\vec{R})$.

iii) The cross product between two parallel vectors gives a null vector.

$\vec{P}\times\vec{Q} = PQ\sin\theta\hat{n} = \vec{0}$, when $\theta = 0°$ (or) $180°$ (or) $|\vec{P}\times\vec{Q}| = 0$.

iv) The cross product between two mutually perpendicular vectors is maximum.

From $\vec{P}\times\vec{Q} = PQ\sin\theta\hat{n}$, when $\theta = 90°$

$\vec{P}\times\vec{Q} = PQ\hat{n}$ is the vector with maximum magnitude 'PQ'.

Examples:

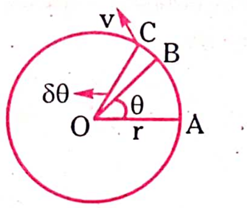
1) Angular momentum is the cross product of position vector $(\vec{r})$ and linear momentum $(\vec{p})$ and is expressed as $\vec{L} = \vec{r}\times\vec{p}$.

2) Torque is the cross product of position vector $(\vec{r})$ and force $(\vec{F})$.

$\therefore\ \vec{\tau} = \vec{r}\times\vec{F}$.

05. Define angular velocity (ω). Derive $v = r\omega$. **AP Mar 19, May 14; TS Mar 16, 17, 19, May 22**

Ans: **Angular velocity:** The rate of change of angular displacement of a particle is called angular velocity. i.e., $\omega = \frac{d\theta}{dt}$.



Relation between v and ω: Consider a particle moving on the circumference of a circle of radius 'r'. At $t = 0$ its position is at 'A'. At any time 't', let the angular displacement of the particle be 'θ'. If the particle is further displaced through an angle '$\delta\theta$' in a further time interval 'δt',

then the instantaneous angular velocity 'ω' at this instant of time $\omega = \lim_{\delta t\to 0}\left(\frac{\delta\theta}{\delta t}\right) = \frac{d\theta}{dt}$ —— (1)

At this instant of time, the linear velocity of the particle is given by

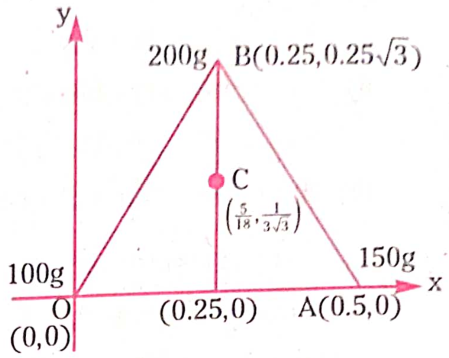
$$v = \lim_{\delta t\to 0}\frac{BC}{\delta t} = \lim_{\delta t\to 0}\frac{r\delta\theta}{\delta t} \quad \text{(arc length (BC) = radius} \times \text{angle)}$$

$$V = r\left(\lim_{\delta t\to 0}\frac{\delta\theta}{\delta t}\right) = r\frac{d\theta}{dt} \quad —— (2)$$

From (1) & (2), $v = r\omega$.

06. Find the centre of mass of three particles at the vertices of an equilateral triangle. The masses of the particles are 100 g, 150 g and 200 g respectively. Each side of the equilateral triangle is 0.5 m long. AP & TS Mar 18

Ans: With the x and y axes chosen as shown in figure, the coordinates of points O, A and B forming the equilateral triangle are respectively $(0,0)$, $(0.5,0)$, $(0.25, 0.25\sqrt{3})$. Let the masses 100 g, 150 g and 200 g be located at O, A and B respectively.



Then $x = \dfrac{m_1x_1 + m_2x_2 + m_3x_3}{m_1 + m_2 + m_3}$

$$\Rightarrow x = \frac{[100(0) + 150(0.5) + 200(0.25)]\text{gm}}{(100 + 150 + 200)\text{g}}$$

$$= \frac{75 + 50}{450}\text{m} = \frac{125}{450}\text{m} = \frac{5}{18}\text{m},$$

$$y = \frac{[100(0) + 150 + 200(0.25\sqrt{3})]\text{gm}}{450\text{ g}} = \frac{50\sqrt{3}}{450}\text{m} = \frac{\sqrt{3}}{9}\text{m} = \frac{1}{3\sqrt{3}}\text{m}.$$

The centre of mass 'C' is shown in the figure. Note that it is not the geometric centre of the triangle OAB.

07. Find the torque of a force $7\hat{i} + 3\hat{j} - 5\hat{k}$ about the origin. The force acts on a particle whose position vector is $\hat{i} - \hat{j} + \hat{k}$. AP Mar 14

Ans: Given $\vec{r} = \hat{i} - \hat{j} + \hat{k}$ and $\vec{F} = 7\hat{i} + 3\hat{j} - 5\hat{k}$

Then torque $\vec{\tau} = \vec{r} \times \vec{F} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 1 & -1 & 1 \\ 7 & 3 & -5 \end{vmatrix} = \hat{i}(5-3) - \hat{j}(-5-7) + \hat{k}(3-(-7)) = 2\hat{i} + 12\hat{j} + 10\hat{k}$.

08. The moment of inertia of a flywheel making 300 revolutions per minute is 0.3 kg m^2. Find the torque required to bring it to rest 20s. Mar 20

Ans: Initial angular velocity $\omega_0 = \dfrac{2\pi n}{t} = \dfrac{2\pi \times 300}{60} = 10\,\pi\text{ rad s}^{-1}$,

Final angular velocity, $\omega = 0$

$$\tau = I\alpha = \frac{I(\omega - \omega_0)}{t} = \frac{0.3 \times 10\pi}{20} = \frac{0.3 \times 3.14}{2} = 0.471\text{ Nm}.$$

VERY SHORT ANSWER QUESTIONS (2 MARKS)

09. Is it necessary that a mass should be present at the centre of mass of any system ?
AP Mar 11, May 11, 12, 14, 16; TS May 22

Ans: No, it is not necessary that mass should be present at the centre of mass of any system.

Eg: In case of a uniform ring or a bangle, there is no mass present at its centre.

10. Why are spokes provided in a bicycle wheel ? May 14

Ans: The spokes of cycle wheel increases its moment of inertia. The greater is the moment of inertia, the more is the opposition to any change in uniform rotational motion. As a result, cycle runs smoothly and steadily.

11. We cannot open or close the door by applying force at the hinges. Why ?

AP May 16, TS May 22

Ans: Opening or closing the door by applying the force is a turning effect or torque. We know $\vec{\tau} = \vec{r} \times \vec{F}$. At the hinges, $\vec{r} = 0$ so $\vec{\tau} = \vec{0}$. Hence, no turning effect.

12. By spinning eggs on a table top, how will you distinguish a hard boiled egg from a raw egg ?

AP Mar 13; TS May 22

Ans: $\tau = I\alpha = \text{constant}$, $\alpha \propto \frac{1}{I}$.

Moment of inertia of raw egg is more than that of boiled egg. When the same torque is applied on both the eggs, boiled egg spins more faster than raw egg.

13. Why is it easier to balance a bicycle in motion ? TS Mar 19

Ans: The rotating wheels of a bicycle possesses angular momentum. In the absence of external torque neither the magnitude nor the direction of angular momentum change. The direction of angular momentum is along the axis of the wheel. So the bicycle does not get tilted.

THE END

08 Oscillations

LAQ (1) - 1 × 8 = 8M
SAQ (0) - 0 × 4 = 0M
VSAQ(0) - 0 × 2 = 0M
Total Marks = 8M

LONG ANSWER QUESTIONS (8 MARKS)

01. a) Show that the motion of a simple pendulum is simple harmonic and hence derive an equation for its time period. What is seconds pendulum ?

AP Mar 15, 16, 17, 20, May 17, June 15; TS Mar 15, 17, 18, 20, May 16, 17

b) The mass and radius of a planet are doubled that of the earth. If the time period of a simple pendulum on the earth is 'T', then find the time period on the planet.

AP Mar 20; UNSOLVED PROBLEM

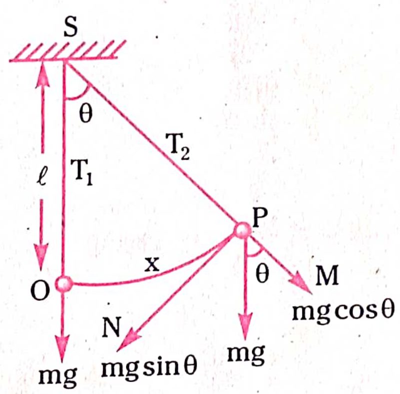
c) Calculate the change in the length of a simple pendulum of length 1 m, when its period of oscillation changes from 2 s to 1.5 s.

TS Mar 18; UNSOLVED PROBLEM

d) Find the length of a simple pendulum which ticks seconds. $(g = 9.8\ ms^{-2})$

AP Mar 17, 18; TS Mar 17

Ans: a) Consider a simple pendulum with a bob of mass 'm' as shown in figure. Let 'S' be the point of suspension and, 'ℓ' be the length of the pendulum. At the equilibrium position 'O', the tension T_1 in the string balance the weight 'mg' of the bob.



Suppose the bob is given a small angular displacement 'θ' and left free. Then the bob oscillates to and fro about the equilibrium position 'O'. Let 'P' is a point with angular displacement 'θ' of the pendulum as shown in the figure $(\angle OSP = \theta)$.

Then the length of the arc, OP is given by $OP = x = \ell\theta$ (or) $\theta = \left(\frac{x}{\ell}\right)$ ——— (1)

The force acting on the bob at point 'P' is given as

i) The weight of the bob $(W = mg)$ acts vertically downwards and

ii) The tension in the string $(T = T_2)$ along PS.

Suppose the weight 'mg' is resolved into two rectangular components as shown in the figure.

1) $mg\cos\theta$ along PM and

2) $mg\sin\theta$ at right angle to PM along PN.

Balancing of forces at P:

i) The component $mg\cos\theta$ balances the tension T_2 i.e., $T_2 = mg\cos\theta$.

ii) The component $mg\sin\theta$ is the unbalanced force which acts towards the mean position along PN.

The unbalancing force is called restoring force.

$\therefore$ Restoring force $F = -mg\sin\theta$

$$\therefore a = \frac{-mg\sin\theta}{m} = -g\sin\theta \quad \text{—— (2)}$$

when 'θ' is very small $\sin\theta \approx \theta$ and equation (2), becomes as $a = -g\theta$

Using equation (1) in equation (2), we can write

$$a = -g\left(\frac{x}{\ell}\right) \quad \text{—— (3)}$$

$-$ve sign indicates that 'a' and 'x' are in opposite direction, since 'g' and 'ℓ' are constants we have $a \, \alpha -x$ i.e., acceleration is directly proportional to the displacement and 'a' is directed towards the equilibrium position 'O'. Hence, the oscillations are simple harmonic. The period of oscillation of simple pendulum is given by

$$T = 2\pi\sqrt{\frac{\text{displacement}}{\text{acceleration}}} = 2\pi\sqrt{\frac{x}{a}} \quad \text{—— (4)}$$

From equation (3), $\frac{x}{a} = \frac{\ell}{g}$ (taking magnitudes only)

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

The time period is independent of the amplitude of oscillation as long as the amplitude is so small such that the bob oscillates along a straight line.

Seconds pendulum: The pendulum whose time period is two seconds is called seconds pendulum.

b) Mass of planet $M_P = 2M_e$, Radius of planet $R_P = 2R_e$.

Time period of pendulum on earth $= T$.

Time period on planet $= T' = ?$

$$g_e = \frac{GM}{R^2}, \; g_P = \frac{G.2M}{(2R)^2} = \frac{GM}{2R^2} = \frac{g_e}{2}$$

$$T = 2\pi\sqrt{\frac{\ell}{g_e}} \text{ on the earth; } T' = 2\pi\sqrt{\frac{\ell}{g_p}} \text{ on the planet .}$$

$$\therefore \frac{T'}{T} = \sqrt{\frac{g_e}{g_p}} = \sqrt{2} \text{ (or) } T' = \sqrt{2}T.$$

c) For seconds pendulum $T_1 = 2\,\text{sec}$, Length $\ell_1 = 1\,\text{m}$,

New time period $T_2 = 1.5\,\text{sec}$, Length $\ell_2 = ?$

As $T \propto \sqrt{\ell}$.

$$\frac{T_2}{T_1} = \sqrt{\frac{\ell_2}{\ell_1}} \Rightarrow \left(\frac{1.5}{2}\right)^2 = \frac{\ell_2}{\ell_1} \Rightarrow \frac{9}{16} = \frac{\ell_2}{1} \Rightarrow \ell_2 = \frac{9}{16}\text{m}$$

$\therefore$ Decrease in length $\Delta\ell = \ell_1 - \ell_2 = 1 - \frac{9}{16} = \frac{7}{16}\text{m} = 0.4375\text{ m}$.

d) 1) The time period of a simple pendulum, which ticks seconds is $T = 2s$.

2) We take $g = 9.8\ ms^{-2}$ and $\pi^2 = 9.8$.

3) Formula: $T = 2\pi\sqrt{\frac{L}{g}} \Rightarrow T^2 = 4\pi^2\frac{L}{g} \Rightarrow L = \frac{gT^2}{4\pi^2}$.

4) Length of the simple pendulum $L = \frac{gT^2}{4\pi^2} = \frac{9.8\times 2^2}{4\pi^2} = \frac{9.8\times 4}{4(9.8)} = 1\ m$.

02. **a) Define simple harmonic motion. Show that the motion of (point) projection of a particle performing uniform circular motion, on any diameter, is simple harmonic.**

AP May 14, 16; Mar 18, 19; TS June 15, Mar 16, 19, May 18, 19

b) On an average a human heart is found to beat 75 times in a minute. Calculate its frequency and period. **AP Mar 19**

c) A mass of 2 kg is a attached to spring of force constant $200\ Nm^{-1}$. Find its time period.

TS Mar 19; ADD. PROBLEM

Ans: **a) Definition of SHM:** A body is said to be in simple harmonic motion provided.

i) The motion should be to and fro and is periodic about a fixed point.

ii) The acceleration should always be directed towards the mean position and is always directly proportional to the displacement from the mean position.

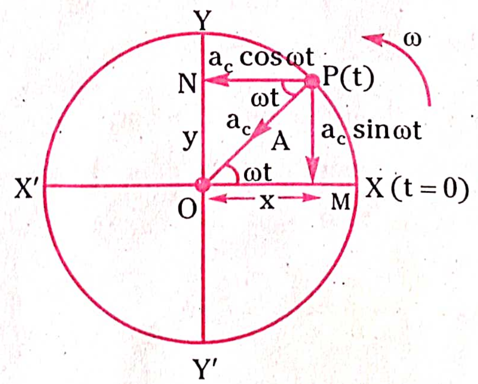
iii) Acceleration and displacement are always in opposite direction.

Consider a particle 'P' moving on a circle of radius 'A' with uniform angular speed 'ω' in anti clock wise direction. As the particle moves on the circumference of circle, its projection 'M' moves on the diameter XX' to and fro about centre 'O'. Suppose the particle starts from position 'X'. After time 't', the position vector of the particle covers an angle of 'ωt' with +ve x-axis as shown in figure. During this time, the projection 'M' of the position vector of the particle on x-axis covers a displacement 'x'.

$\therefore$ From triangle OMP, we have $\cos\omega t = \frac{x}{A}$

$\Rightarrow x = A\cos\omega t$ —— (1)

Reference cycle



The magnitude of acceleration of projection 'M' is equal to the component of centripetal acceleration of the particle, parallel to the diameter XX'.

$a_M = a_c \cos\omega t$ —— (2)

$a_M = A\omega^2 \cos\omega t$ [$\because$ centripetal acceleration $a_c = A\omega^2$]

From the figure, acceleration of the projection 'M' is opposite to the direction of its displacement 'x'.

i.e., $a_M = -A\omega^2 \cos\omega t$ —— (3)

$a_M = -\omega^2 x$ [$\because x = A\cos\omega t$]

$\therefore a_M \alpha -x$ —— (4)

From this equation, we conclude that in uniform circular motion the projection of a particle on any diameter is in simple harmonic motion.

b) The beat frequency of heart $= 75/1\,\text{min} = 75/60 = 1.25\,\text{Hz}$.

Time period $T = 1/1.25 = 0.8\,\text{S}$.

c) Given that $m = 2\,\text{kg}$, Spring of force constant (k) $= 200\,\text{Nm}^{-1}$

Time period $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{2}{200}} = 2\times3.14\times\frac{1}{10} = 0.628\,\text{S}$.

THE END

09 Gravitation

LAQ (0)	- 0 × 8 = 0M
SAQ (1)	- 1 × 4 = 4M
VSAQ(0)	- 0 × 2 = 0M
Total Marks	= 4M

SHORT ANSWER QUESTIONS (4 MARKS)

01. What is escape velocity ? Obtain an expression for it.

AP Mar 15, 18, 19, May 16, 17; TS Mar 16, 19, May 22

Ans: **Escape velocity:** The minimum velocity with which a body is to be projected, so that it escapes from the gravitational field of a planet is called its escape velocity on the planet.

Expression: Consider a body of mass 'm' (at rest) on the surface of a planet of mass 'M' and radius 'R'.

Suppose the body is thrown with minimum velocity 'v_e' to overcome the gravitational field where the total energy of the body is zero.

Work done to carry the body over the surface of a planet to infinity.

$$(W) = \frac{GMm}{R}$$

If this work done is equal to kinetic energy provided to the body on the surface of the planet, it is escaped over the gravitational field of the planet.

$$\frac{1}{2}mv_e^2 = \frac{GMm}{R} \Rightarrow \frac{v_e^2}{2} = \frac{GM}{R} \text{ (or) } v_e = \sqrt{\frac{2GM}{R}}$$

But, $gR^2 = GM$. We get $v_e = \sqrt{2gR}$

$$v_e = \sqrt{2}v_0 \quad (\because v_0 = \sqrt{gR})$$

i.e., escape velocity of a body is $\sqrt{2}$ times of its orbital velocity.

The escape velocity $v_e = 11.2\text{ km/sec}$, to escape body form surface of earth.

02. What is orbital velocity ? Obtain an expression for it. **Mar & May 14; AP Mar 17, May 18**

Ans: The speed of a satellite in its orbit is called orbital velocity (or) the minimum velocity required for a body in order to revolve around a planet in circular orbital is known as orbital velocity.

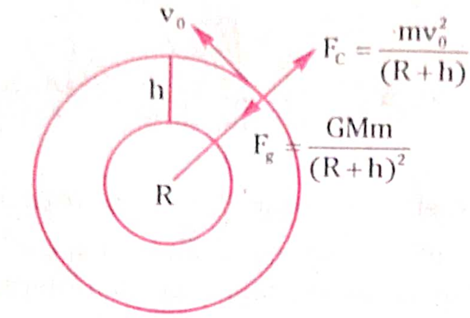
Expression: Consider the earth of mass 'M' and radius 'R'. Suppose a satellite of mass 'm' is revolving around the earth at a height 'h' from the surface of the earth.

$\therefore$ Gravitational force of attraction between the earth and the satellite, $F_g = \frac{GMm}{(R+h)^2}$.

Centrifugal force on the satellite, $F_C = \frac{mv_0^2}{(R+h)}$ where v_0 is orbital velocity.

Here, the necessary centripetal force acting on the satellite is provided by the gravitational force of attraction by the earth on the satellite.

i.e., $\frac{mv_0^2}{(R+h)} = \frac{GMm}{(R+h)^2} \Rightarrow v_0^2 = \frac{GM}{(R+h)} \Rightarrow v_0 = \sqrt{\frac{GM}{(R+h)}}$.



If the satellite is in an orbit close to the earth surface, then the radius of the orbit is approximately equal to the radius of the earth.

$$v_0 = \sqrt{\frac{GM}{R+0}} = \sqrt{\frac{GM}{R}} = \sqrt{gR} \qquad \left(\because g = \frac{GM}{R^2}\right)$$

$\therefore v_0 = \sqrt{gR}$.

The orbital velocity $v_0 = 7.92\ km/sec$.

03. What is a geostationary satellite? State its uses.

AP June 15, Mar 16, 20, May 22; TS Mar 15, 18, May 16, 18, 22 June 15

Ans: The artificial satellite whose time period of revolution is equal to the time period of rotation of the earth is called geostationary satellite. This satellite appears at rest with respect to the earth. The period of revolution of a geostationary satellite is 24 hours. It rotates from west to east in equatorial plane of the earth.

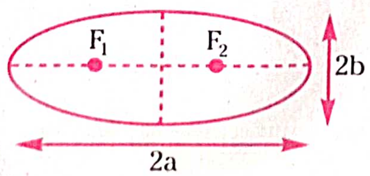
Uses: Geostationary satellites are used

1) to study the upper layers of the atmosphere.
2) in the weather forecast.
3) to know the shape and size of the earth.
4) to identify the minerals and natural resources present inside and on the surface of the earth.
5) to transmit TV programmes to distant places.

04. State Kepler's laws of planetary motion ? **TS Mar 17, 20**

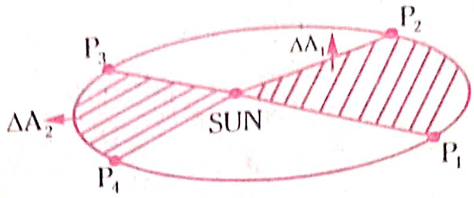
Ans: Kepler proposed three laws to describe the motion of planets round the sun.

1) **Law of orbits:** All planets revolve around the sun in elliptical orbits with the sun at one of the foci of the ellipse.



As shown in figure sun may be at F_1 or F_2. Here 'a' and 'b' are equal to lengths of semi major axis and semi minor axis respectively.

2) **Law of areas:** The line joining a planet to the sun sweeps out equal areas in equal intervals of time.



As shown in figure if a planet moves from P_1 to P_2 or from P_3 to P_4 in the same duration of time, then the areas ΔA_1 and ΔA_2 are equal. From this law, it can be observed that planets move slower when they are farther from the sun and faster when they are nearer to the sun.

Here areal velocity $\frac{dA}{dt} = \text{constant}$.

3) **Law of periods:** The square of the time period of revolution of a planet around the sun is directly proportional to the cube of the semi major axis of the elliptical path. i.e., $T^2 \propto a^3$.

where 'T' is time period of revolution of planet and 'a' is the length of the semi major axis.

05. Derive the relation between acceleration due to gravity (g) at the surface of a planet and gravitational constant (G). **AP May 12**

Ans: Consider a body of mass 'm' placed on the surface of the earth. Consider the earth as a perfect sphere of radius 'R'. Suppose the mass of the earth 'M' is concentrated at its centre.

According to Newton's universal law of gravitation, the force of attraction on the earth by the body $F = \frac{GMm}{R^2}$.

According to Newton's third law, the earth attracts the body with equal force in opposite direction called as weight of the body.

i.e., $W = mg$ where 'g' is the acceleration due to gravity.

But, these two form action-reaction pair.

$$\therefore mg = \frac{GMm}{R^2} \Rightarrow g = \frac{GM}{R^2}.$$

THE END

10 Mechanical Properties of Solids

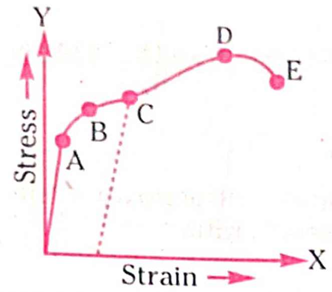
LAQ (0)	- 0 × 8 = 0M
SAQ (1)	- 1 × 4 = 4M
VSAQ(0)	- 0 × 2 = 0M
Total Marks	= 4M

|| SHORT ANSWER QUESTIONS (4 MARKS) ||

01. Describe the behaviour of a wire under, gradually increasing load.
AP Mar 15, 16, 17, 18, 20, May 16; TS Mar 15, 17, 18, 20, May 16, 17, 22; June 15

Ans: To study the behaviour of a metal wire under increasing load, a metal wire is suspended to a rigid support and loaded at the other end. If the load is gradually increased, it breaks after some elongation. If a graph is plotted between the stress on y-axis and the strain on the x-axis, the shape of the graph varies from metal to metal.

Proportionality limit (A): It is the maximum stress applied on the wire upto which stress is directly proportional to strain and Hooke's law is obeyed upto 'A'. So 'OA' is a straight line.



Elastic limit (B): If stress is increased beyond 'A', the wire does not obey Hooke's law. But still elastic nature of the wire exists up to the point 'B'. When the load is removed the wire regains its original size and shape. The point 'B' in the curve is called elastic limit. Then after yield starts so 'B' is called yield point.

Permanent set (C): If the wire is loaded beyond the elastic limit 'B', the wire gets stretched permanently. This behaviour of the wire is shown by the dashed straight line which cuts the x-axis at O′ and OO′ is called permanent set.

Ultimate tensile strength (D): Beyond the point 'C', strain increases rapidly even for a small increase in the stress. The strain increases continuously till the wire reaches a point 'D'. The stress corresponding to 'D' is called ultimate tensile strength of the material.

Breaking point (E): Beyond the point 'D', additional strain is produced even applied force is reduced and the thinning of the wire is no longer uniform. At 'E' the wire ultimately breaks and 'E' is called breaking point.

02. Define strain energy and derive the equation for the same. Mar & May 14; TS May 18, Mar 19
(or) Explain the concept of elastic potential energy in a stretched wire and hence obtain the expression for it.
AP May 17, 18, June 15

Ans: **Strain energy:** The energy stored in a body due to its deformation is called 'strain energy'.

Expression for strain energy: Consider a thin uniform wire of length ℓ and area of corss section A fixed at one end. Let 'F' be the force acting on the free end of a wire.

Workdone to produce a small extension 'de' is $dW = F\,de$

Workdone to produce a total extension 'e' is $W = \int_0^e dW = \int_0^e F de = \int_0^e \frac{YAe}{\ell} de \quad \left(\because F = \frac{YAe}{\ell}\right)$

$= \frac{YA}{\ell}\frac{e^2}{2} = \frac{YAe}{\ell}\frac{e}{2} = \frac{1}{2}Fe$. This is stored as strain energy.

$\therefore$ Strain energy $= \frac{1}{2}Fe$

Strain energy per unit volume $= \frac{\text{Strain energy}}{\text{Volume}} = \frac{1}{2}\frac{Fe}{A\ell}$ ($\because$ Volume of wire $= A\ell$)

Strain energy per unit volume $= \frac{1}{2} \times \text{Stress} \times \text{Strain}$.

03. Define modulus of elasticity, stress, strain and Poisson's ratio.

Ans: **Modulus of elasticity:** Within the elastic limit, the ratio of stress to strain in a body is called modulus of elasticity.

Modulus of elasticity, $E = \frac{\text{stress}}{\text{strain}}$.

Stress: The restoring force developed per unit area of cross-section of the deformed body is called stress.

$\text{Stress} = \frac{\text{restoring force}}{\text{area}} = \frac{F}{A}$.

Strain: The ratio of change in dimension to the original dimension of a body is called strain.

$\text{Strain} = \frac{\text{change in dimension}}{\text{original dimension}}$.

Poisson's ratio: The ratio of lateral contractional strain to the longitudinal elongational strain in a stretched wire is called Poisson's ratio.

Lateral contractional strain $= \frac{-\Delta d}{d}$, longitudinal elongation strain $= \frac{e}{L}$.

Poisson's ration, $\sigma = \frac{\text{lateral contractional strain}}{\text{longitudinal elongational strain}} = \frac{-\Delta d/d}{e/L}$.

04. Define Young's modulus, bulk modulus and rigidity modulus.

Ans: 1) **Young's modulus (Y):** Within elastic limit, the ratio of longitudinal stress to longitudinal strain is called Young's modulus.

Young's modulus $(Y) = \frac{\text{longitudinal stress}}{\text{longitudinal strain}} = \frac{F/A}{e/\ell}$.

2) **Bulk modulus (K):** Within elastic limit, the ratio of volume stress to volume strain is called bulk modulus.

Bulk modulus $(K) = \frac{\text{volume stress}}{\text{volume strain}} = \frac{P}{-(\Delta V/V)}$.

Here, $-$ve sign shows that with increase in pressure, the volume decreases.

3) **Rigidity modulus (η):** Within elastic limit, the ratio of tangential stress to tangential strain is called rigidity modulus (η).

Rigidity modulus $(\eta) = \frac{\text{tangential stress}}{\text{tangential strain}} = \frac{F/A}{\theta}$.

05. Define stress and explain types of stress. **AP Mar 19; TS Mar 16**

Ans: **Stress:** The restoring force developed per unit area of cross-section of the deformed body is called as stress.

$\text{Stress} = \frac{\text{restoring force}}{\text{area}}$.

It is of three types:

1) Longitudinal stress, 2) Volume stress, 3) Shearing stress.

1) Longitudinal stress: The normal force to the surface applied per unit area of cross-section of the body to change its length is called longitudinal stress.

$$\text{Longitudinal stress} = \frac{\text{restoring force}}{\text{area}}.$$

2) Volume stress (or) Bulk stress: The normal force to the surface applied per unit area on a body change its volume is called volume stress.

$$\text{Volume stress} = \text{Pressure} = \frac{\text{normal force}}{\text{area}}$$, it is also called hydraulic stress.

3) Shearing stress (or) Tangential stress: The restoring force per unit area developed due to the applied tangential force is known as tangential (or) shearing stress.

$$\text{Shearing stress} = \frac{\text{tangential restoring force}}{\text{area}}.$$

06. Define strain and explain the types of strain. May 22

Ans: **Strain:** The ratio of change in dimension to the original dimension of a body is called strain.

$$\text{Strain} = \frac{\text{change in dimension}}{\text{original dimension}}.$$

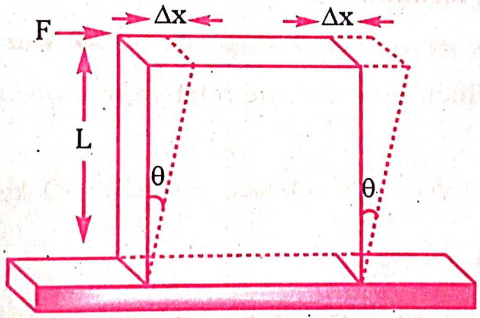
It is of 3 types: 1) Longitudinal strain, 2) Volume strain, 3) Shearing strain.

1) Longitudinal strain: The ratio of change in length due longitudinal force to original length of the body is called longitudinal strain.

$$\text{Longitudinal strain} = \frac{\text{change in length}}{\text{original length}} = \frac{e}{L} \text{ (or) } \frac{\Delta L}{L}.$$

2) Volume strain (or) Bulk strain: The ratio of change in volume due to normal force to original volume of the body is called volume strain.

$$\text{Volume strain} = \frac{\text{change in volume}}{\text{original volume}} = \frac{-\Delta V}{V}.$$



3) Shearing strain: The ratio of relative displacement between two layers due to tangential force to the perpendicular distance between the layers of a body is called shearing strain.

$$\text{Shearing strain} = \frac{\text{relative displacement between two layers}}{\text{perpendicular distance between the layers}} = \frac{\Delta x}{L} = \theta.$$

THE END

11 Mechanical Properties of Fluids

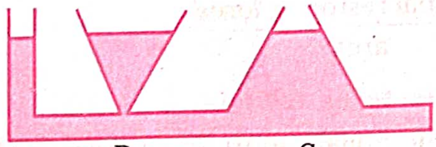
LAQ (0)	- 0 × 8 = 0M
SAQ (0)	- 0 × 4 = 0M
VSAQ(2)	- 2 × 2 = 4M
Total Marks	= 4M

VERY SHORT ANSWER QUESTIONS (2 MARKS)

TS Mar 19

01. What is hydrostatic paradox ?

Ans: **Definition:** Pascal demonstrated that the pressure exerted by a liquid column depends only on the height of the liquid column and not on the shape of the containing vessel. The result is hydrostatic paradox.



Example: Consider three vessels A, B and C of different shapes. They are connected at the bottom by a horizontal pipe. On filling with water the level in the three vessels is same though they hold different amount of water. This is because water at the bottom has the same pressure below each section of the vessel.

02. Define average pressure. Mention its units and dimensional formula. Is it a scalar (or) vector?

AP Mar 17, 20, 22

Ans: Average pressure is defined as the normal force acting per unit area.

$$P_{avg} = \frac{\text{force}}{\text{area}}$$

SI Unit: Nm^{-2} (or) Pascal.

It is a scalar. **Dimensional formula:** $ML^{-1}T^{-2}$.

03. Define viscosity. What are its units and dimensions ? **AP Mar 12, May 16; TS June 15, May 18**

Ans: The property of a fluid which opposes the relative motion between the layers in contact is called viscosity.

The SI unit of coefficient of viscosity is pascal S (Pa.S) (or) $kg\,m^{-1}s^{-1}$ (or) $N\text{-}s/m^2$.

Dimensional formula: $[M^1L^{-1}T^{-1}]$.

04. What is the principle behind the carburetor of an automobile ?

AP Mar 15, 19, June 15; TS Mar 17, 18

Ans: The carburetor of an automobile works on Bernoulli's principle. It has a nozzle in which air flows with large speed. So the pressure is lowered at the nozzle and petrol flows from the chamber to nozzle at low pressure and provides correct mixture of air to fuel for combustion.

05. What is magnus effect ? **AP Mar 15, May 17, 18; TS Mar 16, 19, May 22**

Ans: When the ball is spinning and moving in the air, it experiences a net upward force called dynamic lift. This dynamic lift due to spinning is called 'magnus effect'.

06. Why drops and bubbles are spherical ? AP Mar 16, 17, 18, May 16, 17, 18; TS May 16, 17, 18, 22

Ans: Due to surface tension, the free surface of liquids tend to contract to have minimum surface area. For a given volume, sphere possesses minimum surface area. Hence drops and bubbles are spherical.

07. Give the expression for excess pressure in a liquid drop. TS Mar 17

Ans: Excess pressure in a liquid drop $= \frac{2T}{r}$,

where $T =$ surface tension of the liquid, $r =$ radius of the drop.

08. Give the expression for excess pressure in an air bubble inside the liquid.

AP Mar 19; TS Mar 20

Ans: Excess pressure in an air bubble inside the liquid drop $= \frac{2T}{r}$ (Just below the surface),

where $T =$ surface tension of the liquid, $r =$ radius of the drop.

09. Give the expression for the excess pressure in a soap bubble in air. TS Mar 16, May 22

Ans: A soap bubble has two free surfaces, so excess pressure in a soap bubble in air $= \frac{2T}{r} + \frac{2T}{r} = \frac{4T}{r}$,

where $T =$ surface tension of the liquid, $r =$ radius of the drop.

10. What are water proofing agents and water wetting agents ? What do they do ? AP Mar 20

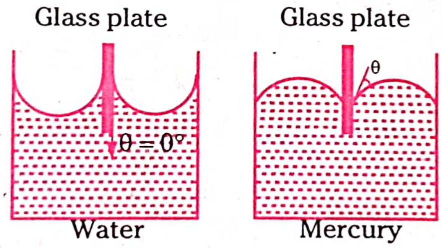
Ans: Water proofing agents increase the angle of contact. **Eg:** Wax.

Water wetting agents reduces the angle of contact. **Eg:** Soaps, detergents.

11. What is angle of contact ? What are its values for pure water and mercury ?

AP May 14, Mar 16; TS Mar 20

Ans: The angle between the tangent to the liquid surface and the solid surface, at the point of contact, inside the liquid is known as angle of contact.



Its value for pure water is $0°$.
Its value for pure mercury is $140°$.

12. If the diameter of a soap bubble is 10 mm and its surface tension is $0.04\ Nm^{-1}$, then find the excess pressure inside the bubble. AP Mar 14, 18, June 15; TS Mar 15, 18, May 16 PROBLEM

Ans: Given, diameter $= 10$ mm, radius $= 5\ mm = 5\times10^{-3}$ m, surface tension $T = 0.04\ Nm^{-1}$

Excess pressure in a bubble $P = \frac{4T}{r} = \frac{4\times0.04}{5\times10^{-3}} = 32\ Nm^{-2}$.

13. Mention any two examples that obey Bernoulli's theorem and justify them ?

AP Mar 18; TS Mar 15

Ans: According to Bernoulli's theorem, pressure is more at a point where the velocity of a fluid is less and vice versa.

Eg-1: Magnus effect: When the ball is spinning and moving in air, its rough surface drags some air around it then the resultant velocity on the top surface of the ball increases and pressure decreases (falls). Similarly, the resultant velocity of the bottom surface of the ball decreases and pressure increases. This creates pressure difference, due to this ball experiences dynamic lift upwards.

Eg-2: Dynamic lift on an air craft wing: when air craft is moving on the runway, the wind flows with high speed on the top of the wings than at the bottom. This creates less pressure at the top and maximum pressure at the bottom of the wing. Due to this pressure difference, the aircraft experiences dynamic lift upwards.

14. The density of the atmosphere at sea level is $1.29\ kg/m^3$. Assume that it does not change with altitude. Then, how high would the atmosphere extend ? EXAMPLE PROBLEM

Ans: Atm pressure $= h\rho g \Rightarrow 1.01\times10^5 = h\times1.29\times9.8 = 7989\ m = 8\ km$ (approx).

15. Calculate the work done in blowing a soap bubble of diameter $0.6\ cm$ against the surface tension (surface tension of soap solution $= 2.5\times10^{-2}\ Nm^{-1}$). PROBLEM

Ans: Given, diameter $= 0.6\ cm$, radius $= 0.3\ cm = 3\times10^{-3}\ m$

Work done in blowing a soap bubble $= 8\pi r^2 T$

$= 8\times3.14\times(3\times10^{-3})^2\times2.5\times10^{-2} = 8\times3.14\times9\times10^{-6}\times2.5\times10^{-2} = 5.65\times10^{-6}\ J$.

THE END

12 Thermal Properties of Matter

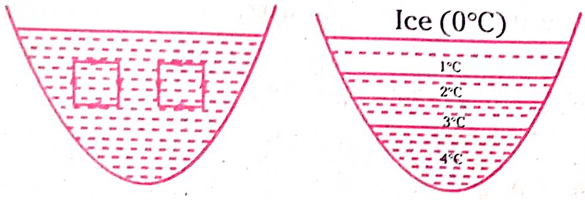
LAQ (0) - 0 × 8 =	0M
SAQ (1) - 1 × 4 =	4M
VSAQ(2) - 2 × 2 =	4M
Total Marks =	8M

SHORT ANSWER QUESTIONS (4 MARKS)

01. In what way does the anomalous behaviour of water advantageous to aquatic animals ?

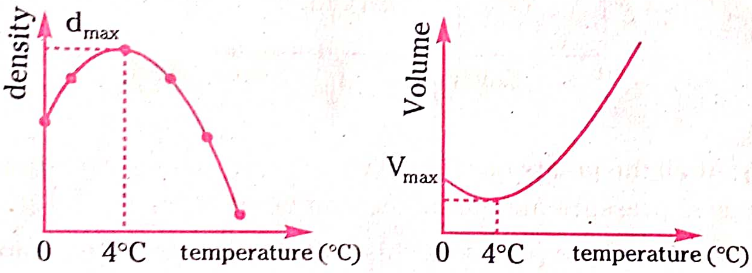
Mar & May 14; AP Mar 17, 18; TS May 18, 22

Ans: All the liquids expand on heating from $0°C$ to $4°C$. So, density decreases from $0°C$ to $4°C$. Whereas water contracts on heating from $0°C$ to $4°C$ and expands thereafter. This peculiar behaviour is called anomalous behaviour of water.



So density of water increases from $0°C$ to $4°C$ and decreases thereafter. So water has maximum density at $4°C$.

Significance:



i) In cold countries, during winter the temperature of atmosphere above water lakes and ponds decreases much below $0°C$.

ii) Due to this, the top most layers of water in ponds gets cooled and becomes denser and they sink to the bottom.

iii) At the same time water at the bottom which is at relatively high temperature becomes lighter and goes up. This process continues till the entire water in lake gets $4°C$.

iv) After $4°C$, if the water at the top is further cooled, then it will not go down due to anomalous expansion of water. This process continues until the top layer of water gets $0°C$.

v) When water at the top of the lake attains $0°C$, it becomes ice and forms a layer at the top.

But the water inside the lake will be at $4°C$, and hence there will be enough water at the bottom of the lake. Hence the aquatic animals like frogs, fishes can survive even in severe winter also.

02. Pendulum clocks generally go fast in winter and slow in summer. Why ? TS Mar 17, 19

Ans: The time period of a pendulum is given by $T = 2\pi\sqrt{\frac{\ell}{g}}$, where '$\ell$' is the length of the pendulum and 'g' is acceleration due to gravity. At the same place ('g' is constant)

$T \propto \sqrt{\ell}$. The length of the pendulum changes with temperature according to $\Delta\ell = \ell\alpha\Delta t$ (or) $\Delta\ell \propto \Delta t$.

i) In summer, length of pendulum increases and time period also increases. When time period increases it goes slow and it makes less number of oscillations per day. So it loses times.

ii) In winter, length of pendulum decreases and time period also decreases. When time period decreases, it goes fast and it makes more number of oscillations per day. So it gains time.

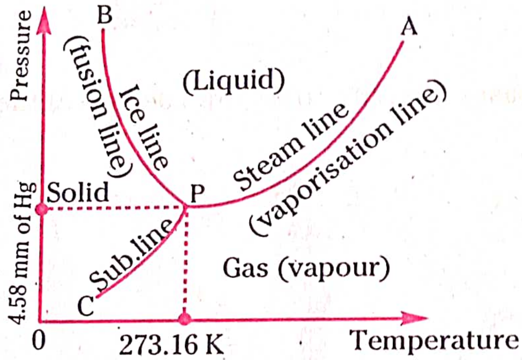
03. Write a short notes on triple point of water. AP Mar 10, 13, 16, May 11, June 10

Ans: **Triple point:** The standard pressure and temperature at which all three states of matter (solid, liquid and vapor) coexist is known as triple point of water.

For water, triple points are $(P,T) = (4.58\text{ mm of Hg}, 273.16\text{ K})$ or $(0.006\text{ atm}, 0.01°C)$.

To study the change of states of water, a graph is drawn between pressure and temperature as shown in phasor diagram.

There are three curves in the phase diagram.



1) **Ice line (PB):** At all the points on this curve, ice and water are in equilibrium. It has negative slope. It means as pressure increases, melting point of ice decreases.

2) **Steam line (PA):** At all the points on this curve, water and steam are in equilibrium. It has positive slope. It means as pressure increases, boiling point of water also increases.

3) **Sublimation line (PC):** At all the points on this curve, ice and steam are in equilibrium. It has positive slope. It means as pressure increases, sublimation point of water also increases.

The intersection of these three curves is triple point.

04. Explain conduction, convection and radiation with examples.

AP Mar 15, 19, 20, May 16; TS Mar 15, 16, 18, 20, June 15

Ans: **Conduction:** The process of transfer of heat energy through a medium without any actual movement of the particles (molecules or atoms) of the medium is called conduction.

Here transfer of heat energy takes place due to collisions between the particles.

Eg: In all solids and in mercury, heat flows by the method of conduction.

Convection: The process of transfer of heat energy through a medium with actual movement of the particles (molecules or atoms) of the medium is called convection.

Eg: In all fluids (liquids and gases), heat flows by the method of convection. See breezes and trade winds are the examples.

Radiation: The process of transfer of heat from one place to another even without the presence of any medium is called radiation.

Eg: Earth receives heat from the sun. The heat from a hot oven is received by a person at some distance.

05. Explain Celsius and Fahrenheit scales of temperature. Obtain the relation between Celsius and Fahrenheit scales of temperature.

TS May 22

Ans: **Celsius (Centigrade) scale of temperature:** In Celsius scale, the lower fixed point (L.F.P) is the ice point having the value $0°C$ and the upper fixed point (U.F.P) is the steam point having the value $100°C$. The interval between these two points $(100°C - 0°C = 100°C)$ is divided into 100 equal parts, and each part is $1°C$.

Fahrenheit scale of temperature: In Fahrenheit scale, the lower fixed point (L.F.P) is the ice point having the value $32°F$ and the upper fixed point (U.F.P) is the steam point having the value $212°F$. The interval between these two points $(212°F - 32°F = 180°F)$ is divided into 180 equal parts, so each part is $1°F$.

Between melting point of ice and boiling point of water,

100 units on Celsius scale $=$ 180 units on Fahrenheit scale.

For any scale of temperature, $\dfrac{\text{reading} - \text{L.F.P}}{\text{U.F.P} - \text{L.F.P}} = \text{constant}$.

To compare readings on Celsius and Fahrenheit scales,

$$\frac{C-0}{100} = \frac{F-32}{180} \Rightarrow \frac{C}{5} = \frac{F-32}{9} \Rightarrow C = \frac{5}{9}(F-32)$$

where 'F' and 'C' are the readings on Fahrenheit scale and Celsius Scale.

VERY SHORT ANSWER QUESTIONS (2 MARKS)

06. Distinguish between heat and temperature.

TS Mar 15, 20

Ans: Heat is a form of energy that is transferred from a body at high temperature to a body at low temperature.

It is a scalar and its SI unit is joule (J).

Temperature is a fundamental physical quantity which defines the thermal state of a body. It is the degree of hotness or coldness of the body.

It is a scalar and its SI unit is Kelvin.

Heat is a cause and Temperature is the effect.

07. Why gaps are left between rails on a railway track ?

AP June 15, Mar 16, 17, 19, May 16, 22; TS Mar 19

Ans: In the construction of railway track, a small gap is to be left between successive rails to allow linear expansion during summer.

08. What are the lower and upper fixed points in Celsius and Fahrenheit scales ?

May 14; AP Mar 16, 18, 19; TS Mar 16

Ans: In Celsius scale, lower fixed point is $0°C$ and upper fixed point is $100°C$.

In Fahrenheit scale, lower fixed point is $32°F$ and upper fixed point is $212°F$.

09. Can a substance contract on heating ? Give an example.

AP Mar 16, 18, May 16; TS May 16, 18

Ans: Yes, some substances contract on heating.

Example: Indian rubber, type metal, cast iron, pure water from $0°C$ to $4°C$.

AP May 17; TS May 17

10. What is latent heat of fusion ?

Ans: The amount of heat required to convert unit mass of a substance from solid state to liquid state at constant temperature is called latent heat of fusion.

$Q = mL$, where 'm' is mass of the substance and 'L' is Latent heat of the substance.

Eg: Latent heat of fusion of ice is $80\,cal\,g^{-1}$ (or) $0.336 \times 10^6\ Jkg^{-1}$.

AP Mar 13

11. What is latent heat of vaporisation ?

Ans: The amount of heat required to convert unit mass of a substance from liquid state to gaseous state at $Q = mL$, where 'm' is mass of the substance and 'L' is latent heat of the substance.

Eg: Latent heat of vaporisation of water is $540\,cal\,g^{-1}$ (or) $2.26 \times 10^6\ J\,kg^{-1}$.

12. What is specific gas constant ? Is it same for all gases ?

Ans: i) Specific gas constant is the gas constant for 1 gram of a gas. It varies from gas to gas. It depends on mass and nature of the gas.

$$\therefore r = \frac{PV}{mT} \text{ (or) } r = \frac{R}{M}.$$

ii) No, 'r' is not same for all gases because molecular weight (M) is different for different gases.

13. What are the units and dimensions of specific gas constant ? AP Mar 14

Ans: Specific gas constant $r = \frac{R}{M}$.

Its S.I unit is $J\,kg^{-1}K^{-1}$. Its Dimensional formula is $[M^0L^2T^{-2}K^{-1}]$.

14. Why utensils are coated black ? Why the bottom of the utensils are made of copper ?

TS Mar 18

Ans: i) Black colour is a good absorber and good emitter of heat. In order to absorb more heat energy, the outside of the utensils are coated black.

ii) The bottom of the utensils are made of copper because copper is a good conductor of heat. Copper conducts the distribution of heat at the bottom of a vessel for uniform cooking.

15. State Wien's displacement law ? AP Mar 17; TS Mar 20

Ans: According to Wien's Displacement law, the wave length corresponding to maximum intensity of radiation emitted by a black body is inversely proportional to its absolute temperature.

i.e., $\lambda_m \propto \frac{1}{T}$ (or) $\lambda_m T = b$, where 'b' is Wien's constant. Its value is 2.9×10^{-3} mK.

16. Ventilators are provided in rooms just below the roof. Why ? AP Mar 14, 20

Ans: When the air in the room gets heated then its density decreases, hence the hot air rises up to the roof due to convection of heat. This hot air escapes through the ventilators placed just below the roof.

17. Define emissive power and emissivity.

Ans: i) The energy radiated by a body per unit time per unit surface area at a given wave length range and at given temperature is called emissive power of the body.

$$E_\lambda = \frac{dQ_\lambda}{d\lambda}.$$

ii) The ratio of the emissive power of a body to that of a black body at the same temperature is called emissivity.

$e = \frac{E_\lambda}{e_\lambda}$, where e_λ is emissive power of the black body.

18. **What is greenhouse effect ? Explain global warming.** AP Mar 15; TS Mar 16, May 16

Ans: i) **Green house effect:** When earth receives sunlight, it gets heated up and emits infrared radiation into air. But this radiation is absorbed by green house gases (CO_2, CH_4, N_2O, O_3 etc) present in the air. Then heat is reradiated in from green house gases in all directions. As part of this reradiated rays travelled back towards the earth surface and lower atmosphere. So, earth's surface and atmosphere gets heated. This is called green house effect.

ii) **Global warming:** Global warming is defined as an average increase in the temperature of the atmosphere near the earth's surface and in the troposphere. It leads to changes in global climate patterns.

19. **Define absorptive power of a body. What is the absorptive power of a perfect black body ?** May 14

Ans: The ratio of the radiant energy absorbed per unit time by unit surface area of the body, to the total energy incident per unit time on unit surface area is called absorptive power (a_λ) of the body.

Absorptive power of a perfectly black body (a_λ) is equal to 1.

20. **State Newton's law of cooling.** AP June 15, Mar 20, May 17, 18; TS Mar 18, May 16

Ans: **Newton's law of cooling:** The rate of loss of heat of a hot body is directly proportional to difference of temperature of the body and its surroundings.

i.e., $\frac{-dQ}{dt} \propto (\theta - \theta_0)$ here, $dQ = msd\theta$ $\left(\because \theta = \frac{\theta_1 + \theta_2}{2}\right)$

$\Rightarrow ms\frac{d\theta}{dt} = -K(\theta - \theta_0)$ where 'K' is proportionality constant (or) $\frac{d\theta}{dt} \propto (\theta - \theta_0)$

i.e., the rate of cooling is directly proportional to the temperature difference between the body and the surroundings.

21. **State the condition under which Newton's law of cooling is applicable.**

Ans: Newton's law of cooiing is applicable, when

i) temperature of the body is uniformly distributed over it.

ii) temperature differences are moderate.

iii) loss of heat is negligible by conductor.

iv) loss of the heat occurs in a streamlined flow of air, i.e., forced convection.

22. **The roof of buildings are often painted white during summer. Why ?** AP May 16; TS Mar 15, 17

Ans: White paint is a good reflector of heat and is a bad absorber of heat. So when white paint is coated on the roof, the buildings are kept cool.

23. **What is the temperature for which the readings on Kelvin and Fahrenheit scales are same ?** PROBLEM

Ans: Given, $F = K = x$

$$\frac{K-273}{100} = \frac{F-32}{180} \Rightarrow \frac{x-273}{100} = \frac{x-32}{180}$$

$$\Rightarrow 9(x-273) = 5(x-32) \Rightarrow 9x - 273\times 9 = 5x - 32\times 5 \Rightarrow 9x - 5x = 2457 - 160 \Rightarrow 4x = 2297$$

$$\therefore x = \frac{2297}{4} = 574.25^\circ.$$

24. **Find the increase in temperature of aluminium rod if its length is to be increased by 1%. (α for aluminium $= 25\times10^{-6}/°C$)** AP Mar 15, June 15, May 22; PROBLEM

Ans: Given, initial length of the rod $\ell_1 = 100$ units, Final length of the rod $\ell_2 = 101$ units

Coefficient of linear expansion of aluminium is $\alpha = 25\times10^{-6}/°C$

Increase in temperature $(t_2 - t_1) = ?$

$$\alpha = \frac{(\ell_2-\ell_1)}{\ell_1(t_2-t_1)} \Rightarrow (t_2-t_1) = \frac{\ell_2-\ell_1}{\alpha(\ell_1)} = \frac{1}{25\times10^{-6}\times100} = \frac{1}{25\times10^{-4}} = \frac{10^4}{25} = \frac{100\times100}{25} = 400°C.$$

25. **Why is it easier to perform the skating on the snow ?** TS Mar 16

Ans: At the time of skating, pressure increases and melting point of ice decreases so that ice melts. The skater skates easily.

26. **Why do liquids have no linear and areal expansions ?** TS Mar 19

Ans: Liquids have no shape on their own. They attain the shape of the container. Liquids are not measured in length wise and area wise so liquids have no linear and areal expansions.

27. **If the maximum intensity of radiation for a black body is found at 1.45 µm, then what is the temperature of a radiating body (Wiens constant $= 2.9\times10^{-3}$ mK).** TS Mar 19

Ans: $\lambda_{max} = 1.45\ \mu m = 1.45\times10^{-6}m$.

Wiens constant $b = 2.9\times10^{-3}$ mK

$$\lambda_{max}T = b\ \text{(constant)} \Rightarrow T = \frac{b}{\lambda_{max}} = \frac{2.9\times10^{-3}}{1.45\times10^{-6}} = 2000\ K.$$

THE END

13 Thermodynamics

LAQ (I) - 1 × 8 = 8M	
SAQ (0) - 0 × 4 = 0M	
VSAQ(0) - 0 × 2 = 0M	
Total Marks = 8M	

LONG ANSWER QUESTIONS (8 MARKS)

01. a) Explain reversible and irreversible processes. Describe the working of Carnot engine. Obtain an expression for the efficiency.

Mar 14; AP Mar 16, 17, 18, 20, May 16, 17, 18; TS Mar 15, 17, 19, May 17

b) A refrigerator is to maintain eatables kept inside at 9°C. If room temperature is 36°C, then calculate the coefficient of performance.

AP Mar 20

Ans: a) Reversible process: A process that can be retraced back in the opposite direction in such a way that system passes through the same states as in direct process and finally the system and the surroundings return to their original states is called a reversible process.

A process is reversible only if it is a quasi-state and there is no loss of energy.

Eg: Melting of ice and vapourisation of water.

Irreversible process: A process that cannot be retraced back in the opposite direction is called an irreversible process.

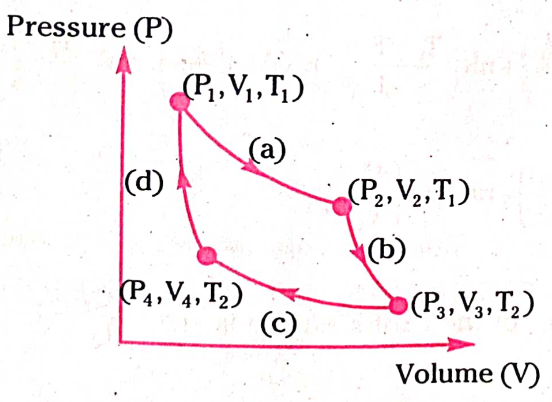
All the spontaneous natural processes are irreversible.

Eg: Free expansion of a gas and work done against friction.

Carnot's engine: A reversible heat engine operating between two different temperatures is called a Carnot engine.

It consists of a source at high temperature, working substance, insulating stand and a sink at low temperature.

Carnot engine undergoes following processes:



i) Isothermal expansion: The system containing "n" moles of an ideal gas is placed on the source and the gas is allowed to expand slowly at constant temperature T_1 by absorbing heat Q_1. This isothermal expansion is represented by the curve (a) in the indicator diagram.

Isothermal expansion of the gas changes its state from (P_1, V_1, T_1) to (P_2, V_2, T_1). The heat absorbed by the gas Q_1 from the source is equal to the work done by the gas and is given by $W_1 = Q_1 = nRT_1 \ell n\left(\frac{V_2}{V_1}\right)$ ——— (1)

ii) **Adiabatic expansion:** The system is then placed on the non conducting stand and the gas is allowed to expand adiabatically till the temperature falls from T_1 to T_2. This adiabatic expansion is represented by the curve (b).

Adiabatic expansion of the gas changes its state from (P_2, V_2, T_1) to (P_3, V_3, T_2). The work done by the gas is $W_2 = nR\left(\frac{T_1 - T_2}{\gamma - 1}\right)$ ——— (2)

iii) **Isothermal compression:** The system is next placed on the sink and the gas is compressed at constant temperature T_2 by rejecting heat Q_2 to the sink. It is represented by the curve (c).

Isothermal compression of the gas changes its state from (P_3, V_3, T_2) to (P_4, V_4, T_2). The heat released by the gas (Q_2) to the sink is equal to the work done on the gas and is given by $W_3 = Q_2 = nRT_2 \ell n\left(\frac{V_3}{V_4}\right)$ ——— (3)

iv) **Adiabatic compression:** Finally the system is again placed on the non-conducting stand and the compression is continued so that the gas returns to its initial state along the curve (d).

Adiabatic compression of the gas changes its state from (P_4, V_4, T_2) to (P_1, V_1, T_1). The work done on the gas is $W_4 = nR\left(\frac{T_1 - T_2}{\gamma - 1}\right)$ ——— (4)

Total work done by the gas in one complete cycle is $W = W_1 + W_2 - W_3 - W_4$

$$\Rightarrow W = nRT_1 \ell n\left(\frac{V_2}{V_1}\right) + nR\left(\frac{T_1 - T_2}{\gamma - 1}\right) - nRT_2 \ell n\left(\frac{V_3}{V_4}\right) - nR\left(\frac{T_1 - T_2}{\gamma - 1}\right)$$

$$\Rightarrow W = nRT_1 \ell n\left(\frac{V_2}{V_1}\right) - nRT_2 \ell n\left(\frac{V_3}{V_4}\right).$$

The efficiency 'η' of the carnot engine is $\eta = 1 - \frac{Q_2}{Q_1} = 1 - \left(\frac{T_2}{T_1}\right)\frac{\ell n(V_3 / V_4)}{\ell n(V_2 / V_1)}$ ——— (5)

Since (b) is an adiabatic process,

$$T_1 V_2^{\gamma-1} = T_2 V_3^{\gamma-1} \Rightarrow \frac{T_2}{T_1} = \left(\frac{V_2}{V_3}\right)^{\gamma-1} \text{ ——— (6)}$$

Similarly, since (d) is an adiabatic process,

$$T_2V_4^{\gamma-1} = T_1V_1^{\gamma-1} \Rightarrow \frac{T_2}{T_1} = \left(\frac{V_1}{V_4}\right)^{\gamma-1} \quad \text{------ (7)}$$

From Eq. (6) and (7), we get $\frac{V_2}{V_3} = \frac{V_1}{V_4} \Rightarrow \frac{V_2}{V_1} = \frac{V_3}{V_4}$ ------ (8)

From Eq. (5) and (8), we get $\eta = 1 - \frac{T_2}{T_1}$.

b) Here, $T_1 = 36°C = 36 + 273 = 309\,K$; $T_2 = 9°C = 9 + 273 = 282\,K$.

Coefficient of performance $= \frac{T_2}{T_1 - T_2} = \frac{282}{309 - 282} = \frac{282}{27} = 10.44$.

02. State second law of thermodynamics. How is heat engine different from a refrigerator ?

May 14; AP Mar 15, 16, 19, June 15; TS Mar 16, 18, 20, May 16, 18

Ans: Second law of thermodynamics:

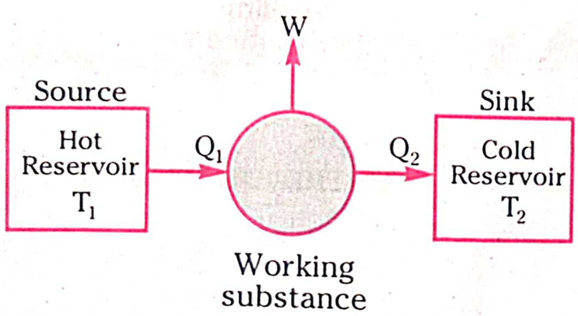
a) **Kelvin Planck statement:** It is impossible to construct a heat engine which can completely convert heat energy supplied to it into useful work.

b) **Clausius statement:** It is impossible for a self acting machine unaided by any external agency to transfer heat energy from a body at lower temperature to a body at higher temperature.

Heat engine:

Heat engine is a device which converts heat energy into work.

It consists of the following essential parts:



1) **Source (hot reservoir):** It is maintained at high temperature (T_1). Heat is extracted by the working substance from this body with out change in its temperature. Its thermal capacity is infinite.

2) **Working substance:** In steam engine working substance is steam and in diesel engine working substance is mixing of fuel vapour and air. It absorbs certain amount of heat from the source, converts a part of it into work and rejects the remaining heat to the sink.

3) **Sink (Cold reservoir):** It is maintained at low temperature (T_2). It absorbs the heat rejected by working substance with out any change in its temperature. Its thermal capacity is infinite.

The working substance taken through a cyclic process. So the internal energy of the working substance does not change.

Working substance absorbs heat Q_1 from the source and rejects heat Q_2 to the sink so the work done by the system is $W = Q_1 - Q_2$.

The ratio of work done (W) by the engine to the amount of heat absorbed (Q_1) by the engine is called its efficiency (η).

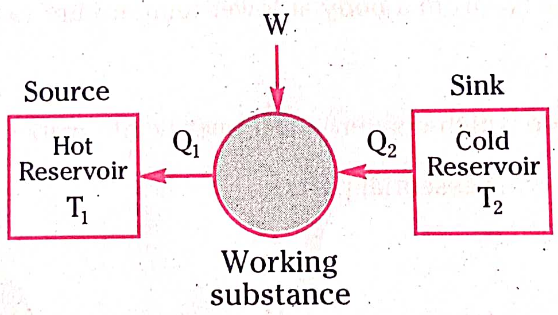
$$\eta = \frac{W}{Q_1} = \frac{Q_2 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1} \text{ Also } \eta = 1 - \frac{T_2}{T_1}.$$

Refrigerator: Refrigerator is an ideal heat engine working in reverse direction and hence it is called as heat pump.

In a refrigerator the working substance extracts an amount of heat Q_2 from the cold reservoir at low temperature T_2. An amount of external work 'W' is done on the working substance and finally an amount of heat Q_1 is rejected to the hot reservoir at a high temperature T_1.

The ratio of heat extracted Q_2 from the cold reservoir to the work done 'W' on the working substance is known as coefficient of performance (β).

i.e., $\beta = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$ also $\beta = \frac{T_2}{T_1 - T_2}$.



THE END

14 Kinetic Theory of Gases

LAQ (0)	- 0 × 8 = 0M
SAQ (0)	- 0 × 4 = 0M
VSAQ(2)	- 2 × 2 = 4M
Total Marks	= 4M

SHORT ANSWER QUESTIONS (4 MARKS)

01. Four molecules of a gas have speeds 1, 2, 3 and 4 km / s. Find rms speed of the gas molecules.

AP May 13

Ans: For the gas rms speed $(v) = \sqrt{\dfrac{v_1^2 + v_2^2 + v_3^2 + v_4^2}{4}}$

$$\Rightarrow v = \sqrt{\frac{1^2 + 2^2 + 3^2 + 4^2}{4}} = \sqrt{\frac{1+4+9+16}{4}} = \sqrt{\frac{30}{4}} = \sqrt{7.5} = 2.74\ \text{km/s}.$$

02. What is the ratio of rms speed of oxygen and hydrogen molecules at the same temperature ?

AP May 14

Ans: For a gas rms velocity

$$v = \sqrt{\frac{3RT}{M}}\ \text{(or)}\ v \propto \frac{1}{\sqrt{M}}\ \text{at constant temperature}$$

$$\text{(or)}\ \frac{v_{O_2}}{v_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{O_2}}} = \sqrt{\frac{2}{32}} = \frac{1}{4}.$$

∴ The ratio of rms speeds of oxygen to hydrogen is $1:4$.

VERY SHORT ANSWER QUESTIONS (2 MARKS)

03. Define mean free path. **AP Mar 15, 17, 18, 19, 20; TS Mar 15, 17, May 18**

Ans: The average distance covered by a molecule between two successive collisions is called mean free path.

Mean free path $(\lambda) = \dfrac{1}{\sqrt{2}n\pi d^2}$.

Here, 'n' is the number of molecules per unit volume and 'd' is the diameter of the molecule.

04. Name two prominent phenomena which provide conclusive evidence of molecular motion.

Ans: 1) Brownian motion, 2) Diffusion.

05. When does a real gas behave like an ideal gas ?

Mar 14; AP Mar 19; TS Mar 16, 19, May 16, 18, June 15

Ans: At low pressures and high temperatures, a real gas behaves like an ideal gas.

06. State Boyle's law and Charles Law ? **AP June 15, Mar 18, 20; TS Mar 15, May 16**

Ans: a) **Boyle's law:** At constant temperature, the pressure of a given mass of a gas is inversely proportional to its volume.

i.e., $P \propto \dfrac{1}{V}$ (or) $PV = K$ (constant).

b) **Charle's 1st law (or) constant pressure law of Charles:** At constant pressure, the volume of a given mass of a gas is directly proportional to its absolute temperature.

i.e., $V \propto T$ (or) $\frac{V}{T} = K$ (constant).

c) **Charle's 2nd law (or) constant volume law of Charles:** At constant volume, the pressure of a given mass of a gas is directly proportional to its absolute temperature.

i.e., $P \propto T$ (or) $\frac{P}{T} = K$ (constant).

Mar 17, 18, 20

07. State Dalton's law of partial pressures.

Ans: The total pressure exerted by a mixture of perfect gases is the sum of the individual pressures that each gas would exert, if it were present alone in the container at the same temperature.

Total pressure $P = P_1 + P_2 + P_3 ...$ where $P_1, P_2, P_3, ...$ partial pressures produced by individual gases.

08 Explain the concept of degrees of freedom for molecules of a gas.

Ans: **Degrees of freedom:** The degrees of freedom of a dynamical system are defined as 'the total number of coordinates (or) independent quantities required to describe completely the position and configuration of the system.

The number of degree of freedom of the system is given by $f = 3N - K$.

where 'N' is number of independent motions and 'K' is number of independent restrictions.

Eg: i) Mono atomic gas molecules possess 3 degrees of freedom $(N = 1,\ K = 0)$

ii) Diatomic gas molecules possess 5 degrees of freedom $(N = 2,\ K = 1)$.

iii) Triatomic gas molecules possess 6 degrees of freedom $(N = 3,\ K = 3)$.

09. What is the expression between pressure and kinetic energy of a gas molecule ?

AP Mar 15, 16, 17, May 18

Ans: The relation between pressure 'p' and kinetic energy of a gas is given by $P = \frac{2}{3}\frac{N\overline{K}}{V}$.

where '$\overline{K}$' is the average kinetic energy of translation per gas molecule, 'N' is number of molecule and 'V' is volume of the gas.

10. When pressure increases by 2%, what is the percentage decrease in the volume of a gas assuming Boyle's law is obeyed ?

Ans: According to Boyle's law, at constant temperature, the pressure of a given mass of a gas is inversely proportional to volume of given mass of the gas.

i.e., $P \propto \frac{1}{V} \Rightarrow PV =$ constant (at constant temperature)

i.e., $P_iV_i = P_fV_f$ (or) $P \propto \frac{1}{V} \propto V^{-1}$

Let $P_i = 100$ and Let $P_f = 102$, then $\frac{V_f}{V_i} = \frac{P_i}{P_f}$ (or) $\left(\frac{V_f}{V_i} - 1\right)100 = \left(\frac{P_i}{P_f} - 1\right) = 100$

$$\Rightarrow \frac{V_f - V_i}{V_i} \times 100 = \frac{P_i - P_f}{P_f} \times 100 = \frac{100 - 102}{102} \times 100 = -1.96.$$

$\therefore$ When pressure of a gas is increased by 2%, then volume is decreased by 1.96%.

11. What is the law of equipartition of energy ?

TS Mar 16, 17, 18

Ans: The law of equipartition of energy, states that this is so for each mode of energy: translational, rotational and vibrational.

That is, in equilibrium, the total energy is equally distributed in all possible energy modes, with each mode having an average energy equal to $\frac{1}{2}k_BT$. This is known as the law of equipartition of energy.

12. If the absolute temperature of a gas is increased to 3 times, what will be the increase in rms velocity of the gas molecule ?

TS June 15, Mar 19, 20

Ans: $v_{rms} = \sqrt{\frac{3K_BT}{m}}$

$v_{rms} \propto \sqrt{T}$ and given $T_1 = T$, $T_2 = 3T$

$$\frac{v'_{rms}}{v_{rms}} = \sqrt{\frac{T_2}{T_1}} = \frac{\sqrt{3T}}{\sqrt{T}} \Rightarrow v'_{rms} = \sqrt{3}v_{rms}.$$

Increase in RMS velocity $v'_{rms} - v_{rms} = \sqrt{3}v_{rms} - v_{rms} = 0.732\ v_{rms}$.

THE END

MODEL PAPER-1

PHYSICS, PAPER-I

Max. Marks: 60

Time: 3 Hours

Note: Read the following instructions carefully.

(i) Answer all questions of Section-A. Answer any six questions of Section-B and any two questions of Section-C.

(ii) In section-A, questions from Sr.No. 1 to 10 are of very short answer type. Each question carries two marks. Every answer may be limited to 5 lines. Answer all these questions at one place in the same order.

(iii) In section-B, questions from Sr.No. 11 to 18 are of short answer type. Each question carries four marks. Every answer may be limited to 10 lines.

(iv) In section-C, questions from Sr.No. 19 to 21 are of long answer type. Each question carries eight marks. Every answer may be limited to 40 lines.

(v) Draw labelled diagrams, wherever necessary for questions in section-B and C.

SECTION-A

I. Answer ALL the following VSAQs: $10 \times 2 = 20$

01. What are the fundamental forces in nature ?
02. Why do we have different units for the same physical quantity ?
03. If $|\vec{a}+\vec{b}| = |\vec{a}-\vec{b}|$ then what is the angle between $\vec{a}$ and $\vec{b}$?
04. What is inertia ? What gives the measure of inertia ?
05. Give the expression for the excess pressure in a liquid drop.
06. Why are drops and bubbles spherical ?
07. Why gaps are left between rails on a railway track ?
08. Distinguish between heat and temperature.
09. What is the expression between pressure and kinetic energy of a gas molecule ?
10. When does a real gas behave like an ideal gas ?

SECTION-B

II. Answer any SIX of the following SAQs: $6 \times 4 = 24$

11. A car travels the first third of a distance with a speed of 10 kmph, the second third at 20 kmph and the last third at 60 kmph. What is its mean speed over the entire distance ?
12. Show that the maximum height reached by a projectile launched at an angle $45°$ is one quarter of the range.
13. Define the terms momentum and impulse. State and explain the law of conservation of momentum. Give example.
14. Define vector product. Explain the properties of a vector product with 2 examples.
15. Find the centre of mass of three particles at the vertices of an equilateral triangle. The masses of the particles are 100 g, 150 g and 200 g respectively. Each side of the equilateral triangle is 0.5 m long.
16. What is a geostationary satellite ? State its uses.
17. Describe the behaviour of a wire under gradually increasing load.
18. Write short notes on Triple point of water.

SECTION-C

III. Answer any TWO of the following LAQs: $2 \times 8 = 16$

19. State and prove law of conservation of energy in case of freely falling body. A pump is required to lift 600 kg of water per minute from a well of 25 m deep and to eject it with speed of $50\,ms^{-1}$. Calculate the power required to perform the above task.
20. Show that the motion of a simple pendulum is simple harmonic and hence derive an equation for its time period. What is seconds pendulum ?
21. State second law of thermodynamics. How is heat engine different form a refrigerator.

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MODEL PAPER-2

PHYSICS, PAPER-I

Time: 3 Hours

Max. Marks: 60

Note: Read the following instructions carefully.

(i) Answer all questions of Section-A. Answer any six questions of Section-B and any two questions of Section-C.

(ii) In section-A, questions from Sr.No. 1 to 10 are of very short answer type. Each question carries two marks. Every answer may be limited to 5 lines. Answer all these questions at one place in the same order.

(iii) In section-B, questions from Sr.No. 11 to 18 are of short answer type. Each question carries four marks. Every answer may be limited to 10 lines.

(iv) In section-C, questions from Sr.No. 19 to 21 are of long answer type. Each question carries eight marks. Every answer may be limited to 40 lines.

(v) Draw labelled diagrams, wherever necessary for questions in section-B and C.

SECTION-A

I. Answer ALL the following VSAQs: **$10 \times 2 = 20$**

01. What is the discovery of C.V. Raman ?
02. Distinguish between Accuracy and Precision.
03. When two right angled vectors of magnitude 7 units and 24 units combine, what is the magnitude of their resultant ?
04. A horse has to exert a greater force during the start of the motion than later. Explain.
05. Define average pressure. Mention it's unit and dimensional formula. Is it a scalar or a vector ?
06. What is angle of contact ?
07. State Newton's law of cooling.
08. State Weins displacement law.
09. State Boyle's law and Charles law.
10. Define mean free path.

SECTION-B

II. Answer any SIX of the following SAQs: **$6 \times 4 = 24$**

11. A man walks on a straight road from his home to a market 2.5 km away with a speed of $5\,kmh^{-1}$. Finding the market closed, he instantly turns and walks back home with a speed of $7.5\,kmh^{-1}$. What is the (a) magnitude of average velocity and (b) average speed of the man over the time interval 0 to 50 min.
12. Show that the trajectory of an object thrown at a certain angle with the horizontal is a parabola.
13. State Newton's second law of motion. Hence derive equation of motion $F = ma$.
14. Distinguish between centre of mass and centre of gravity.
15. Define vector product. Explain the properties of a vector product with 2 examples.
16. What is orbital velocity ? Obtain an expression for it.
17. Explain the concept of Elastic potential energy in a stretched wire and hence obtain the expression for it.
18. Explain Celsius and Fahrenheit scales of temperature. Obtain the relation between Celsius and Fahrenheit scales of temperature.

SECTION-C

III. Answer any TWO of the following LAQs: **$2 \times 8 = 16$**

19. Develop the notions of work and kinetic energy and show that it leads to work-energy theorem.
20. Define simple harmonic motion. Show that the motion of (point) projection of a particle performing uniform circular motion, on any diameter, is simple harmonic.
21. Explain reversible and irreversible processes. Describe the working of Carnot engine. Obtain an expression for the efficiency.

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MODEL PAPER-3

PHYSICS, PAPER-I

Time: 3 Hours **Max. Marks: 60**

Note: Read the following instructions carefully.

(i) Answer all questions of Section-A. Answer any six questions of Section-B and any two questions of Section-C.

(ii) In section-A, questions from Sr.No. 1 to 10 are of very short answer type. Each question carries two marks. Every answer may be limited to 5 lines. Answer all these questions at one place in the same order.

(iii) In section-B, questions from Sr.No. 11 to 18 are of short answer type. Each question carries four marks. Every answer may be limited to 10 lines.

(iv) In section-C, questions from Sr.No. 19 to 21 are of long answer type. Each question carries eight marks. Every answer may be limited to 40 lines.

(v) Draw labelled diagrams, wherever necessary for questions in section-B and C.

SECTION-A

I. Answer ALL the following VSAQs: **$10 \times 2 = 20$**

01. What is Physics ?
02. What is dimensional analysis ?
03. Two forces of magnitudes 3 units and 5 units act at $60°$ with each other. What is the magnitude of their resultant ?
04. If a bomb at rest explodes into two pieces, the pieces must travel in opposite directions. Explain.
05. What is the principle behind the carburetor of an automobile ?
06. Give the expression for the excess pressure in an air bubble inside the liquid.
07. Can a substance contract on heating ? Give an example.
08. Why utensils are coated black ? Why the bottom of the utensils are made of copper ?
09. Define mean free path.
10. The absolute temperature of a gas is increased 3 times. What will be the increase in rms velocity of the gas molecule ?

SECTION-B

II. Answer any SIX of the following SAQs: **$6 \times 4 = 24$**

11. A ball is thrown vertically upwards with a velocity of $20\ ms^{-1}$ from the top of a multistorey building. The height of the point from where the ball is thrown in 25.0 m from the ground. (a) How high will the ball rise ? (b) How long will it be before the ball hits the ground. Take $g = 10\ ms^{-2}$ [Actual value of 'g' is $9.8\ ms^{-2}$]
12. State Parallelogram law of vectors. Derive an expression for the magnitude and direction of the resultant vector.
13. State the laws of rolling friction.
14. Define angular velocity (ω). Derive $v = r\omega$.
15. Distinguish between centre of mass and centre of gravity.
16. What is escape velocity ? Obtain an expression for it.
17. Define strain energy and derive the equation for the same.
18. Explain conduction, convection and radiation with examples.

SECTION-C

III. Answer any TWO of the following LAQs: **$2 \times 8 = 16$**

19. What are collisions ? Explain the possible types of collisions ? Develop the theory of one dimensional elastic collision.
20. Define simple harmonic motion. Show that the motion of (point) projection of a particle performing uniform circular motion, on any diameter, is simple harmonic.
21. State second law of thermodynamics. How is heat engine different from a refrigerator ?

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MODEL PAPER-4

PHYSICS, PAPER-I

Time: 3 Hours **Max. Marks: 60**

Note: Read the following instructions carefully.

(i) Answer all questions of Section-A. Answer any six questions of Section-B and any two questions of Section-C.

(ii) In section-A, questions from Sr.No. 1 to 10 are of very short answer type. Each question carries two marks. Every answer may be limited to 5 lines. Answer all these questions at one place in the same order.

(iii) In section-B, questions from Sr.No. 11 to 18 are of short answer type. Each question carries four marks. Every answer may be limited to 10 lines.

(iv) In section-C, questions from Sr.No. 19 to 21 are of long answer type. Each question carries eight marks. Every answer may be limited to 40 lines.

(v) Draw labelled diagrams, wherever necessary for questions in section-B and C.

SECTION-A

I. Answer ALL the following VSAQs: $10 \times 2 = 20$

01. What is the contribution of S. Chandra Sekhar to physics ?
02. Distinguish between fundamental units and derived units.
03. If $\vec{A} = \vec{i} + \vec{j}$, what is the angle between vector $\vec{A}$ with x-axis ?
04. Can the coefficient of friction be greater than one ?
05. Mention any two examples that obey Bernoullis theorem & justify them.
06. What is magnus effect ?
07. The roof of buildings are often painted white during summer. Why ?
08. Ventilators are provided in rooms just below the roof. Why ?
09. State Dalton's law of partial pressures.
10. State Boyle's law and Charles law.

SECTION-B

II. Answer any SIX of the following SAQs: $6 \times 4 = 24$

11. A ball is dropped from the roof of a tall building and simultaneously another ball is thrown horizontally with some velocity from the same roof. Which ball lands first ? Explain your answer.
12. A force $2\vec{i} + \vec{j} - \vec{k}$ newton acts on a body which is initially at rest. At the end of 20 seconds, the velocity of the body is $4\vec{i} + 2\vec{j} - 2\vec{k}\ ms^{-1}$. What is the mass of the body ?
13. Mention the methods used to decrease friction.
14. Define angular acceleration and torque. Establish the relation between angular acceleration and torque.
15. Define angular velocity (ω). Derive $v = r\omega$.
16. Derive the relation between acceleration due to gravity (g) at the surface of a planet and gravitational constant (G).
17. Describe the behaviour of a wire under gradually increasing load.
18. Pendulum clocks generally go fast in winter and slow in summer. Why ?

SECTION-C

III. Answer any TWO of the following LAQs: $2 \times 8 = 16$

19. Develop the notions of work and kinetic energy and show that it leads to work-energy theorem.
20. Show that the motion of a simple pendulum is simple harmonic and hence drive an equation for its time period. What is seconds pendulum ?
21. State second law of thermodynamics. How is heat engine different from a refrigerator.

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MODEL PAPER-5

PHYSICS, PAPER-I

Max. Marks: 60

Time: 3 Hours

Note: Read the following instructions carefully.

(i) Answer all questions of Section-A. Answer any six questions of Section-B and any two questions of Section-C.

(ii) In section-A, questions from Sr.No. 1 to 10 are of very short answer type. Each question carries two marks. Every answer may be limited to 5 lines. Answer all these questions at one place in the same order.

(iii) In section-B, questions from Sr.No. 11 to 18 are of short answer type. Each question carries four marks. Every answer may be limited to 10 lines.

(iv) In section-C, questions from Sr.No. 19 to 21 are of long answer type. Each question carries eight marks. Every answer may be limited to 40 lines:

(v) Draw labelled diagrams, wherever necessary for questions in section-B and C.

SECTION-A

$10 \times 2 = 20$

I. Answer ALL the following VSAQs:

01. What is the discovery of C.V. Raman ?
02. How can systematic errors be minimized or eliminated ?
03. If $\vec{P} = 2\hat{i} + 4\hat{j} + 14\hat{k}$ and $\vec{Q} = 4\hat{i} + 4\hat{j} + 10\hat{k}$ find the magnitude of $\vec{P} + \vec{Q}$.
04. What happens to the coefficient of friction if weight of the body is doubled.
05. Define Viscosity. What are it's units and dimensions ?
06. Give the expression for the excess pressure in the soap bubble in air.
07. What is greenhouse effect ? Explain global warming.
08. State the conditions under which Newton's law of cooling is applicable.
09. When does a real gas behave like an ideal gas ?
10. Pressure of an ideal gas in container is independent of shape of the container-explain.

SECTION-B

$6 \times 4 = 24$

II. Answer any SIX of the following SAQs:

11. A bullet moving with a speed of $150\,ms^{-1}$ strikes a tree and penetrates 3.5 cm before stopping. What is the magnitude of its retardation in the tree and the time taken for it to stop after striking the tree ?
12. Two balls are projected from the same point in directions 30° and 60° with respect to the horizontal. What is the ratio of their initial velocities if they (a) attain the same height ? (b) have the same range ?
13. Explain the advantages and disadvantages of friction.
14. State and prove the principle of conservation of angular momentum.
15. Define angular velocity (ω). Derive $v = r\omega$.
16. State Kepler's laws of planetary motion.
17. Define stress and explain the types of stress.
18. In what way is the anomalous behaviour of water advantageous to aquatic animals ?

SECTION-C

$2 \times 8 = 16$

III. Answer any TWO of the following LAQs:

19. State and prove law of conservation of energy in case of freely falling body. A machine gun fires 360 bullets per minute and each bullet travels with a velocity of $600\,ms^{-1}$. If the mass of each bullet is 5 gm, find the power of the machine gun.
20. Show that the motion of a simple pendulum is simple harmonic and hence drive an equation for its time period. What is seconds pendulum ? What is the length of a simple pendulum, which ticks seconds ?
21. Explain reversible and irreversible processes. Describe the working of Carnot engine. Obtain an expression for the efficiency.

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